SMPTE

JOURNAL

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78th SMPTE Convention • October 3–7 • Lake Placid Club, Essex Co., N. Y.

JULY 1955 volume 64 • number 7

JOURNAL of the
SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS

PUBLICATION OFFICE: TWENTIETH AND NORTHAMPTON STREETS, EASTON, PA.

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SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS

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Entered as second-class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879, and published monthly. Printed by Mack Printing Company, Easton, Pa.

Journal of the Society of Motion Picture and Television Engineers

VOLUME 64 · NUMBER 7 · JULY 1955

Cameras and Lights for Underwater Use

By HAROLD E. EDGERTON and LLOYD D. HOADLEY

The design of underwater automatic and controlled cameras is discussed. A camera of linear design uses a 4-in. (ID) cylinder and a standard 100-ft roll of 35mm film, exposing 800 frames of double 35mm size. Electronic flash is used for illumination, either synchronized with a shutter when external light is present, or without a shutter in darkness. Simplified calculations are given in chart form for cylinders and end plates with external pressure. A few experimental points are given.

Photography is one of the most powerful methods of taking observational data on the geology and on the marine life in the open sea and on the conditions at the bottom. Almost everyone who is interested in any phase of oceanography at some time desires photographic records to study, or to illustrate his findings or to educate other people. As a result many attempts have been made to obtain underwater photographs. Selected references follow at the end of this article.

Flash lighting, both expendable and electrical, seems to be the most desirable source of illumination for underwater photography. Many recent experimenters have used the electronic flash illumination system, since it permits the production of a large number of pictures per camera lowering. The camera described in this article requires electronic flash to illuminate the 800 exposures that can be made on a standard 100-ft length of 35mm film.

Several types of cameras are required for the various kinds of photographic records that are desired. This paper describes the design of a camera that can readily be adapted to almost any type of photography that requires an automatic recycling mechanism.

Camera Casing Design

Many underwater cameras have been designed by putting a watertight case around a standard camera. The case must be designed to withstand the hydrostatic pressures for the desired depths. For each 32 ft of lowering, the pressure increases by 1 atm; that is, the pressure in pounds per square inch is approximately equal to the depth in feet divided by 2.2. At 1-mile depth the pressure is about 2500 psi. The deepest known spot in the sea is about 36,000 ft, requiring a case that will withstand a pressure of about 17,000 psi.

Two alternatives are open to the camera designer: (1) a casing that will withstand the pressure; and (2) a casing that is automatically filled with air (or liquid) at the right pressure as the camera is lowered into the sea. For the latter type, a thin-walled case can be used. Cousteau uses this second system with high-pressure air on his hand-held motion-picture and still cameras, employing the same demand regulator as used in his Aqualung diving equipment. The liquid-filled camera case design is very inviting but introduces complications for the details of operation of lenses, film, batteries, motors, etc.

Pressure-withstanding camera cases of spherical shape are very desirable from a stress standpoint, but packaging of the internal mechanism is awkward. It is also difficult to provide the access holes for windows and doors.

The next most desirable shape, from stress and construction standpoints, is the cylinder, which is the shape used in the designs shown in this paper. Cylindrical pipes and tubes are available in many standard sizes in many metals and other materials, such as glass.

Since conventional cameras are not easily adaptable to the cylindrical shape, an in-line camera design was evolved about the standard (No. 10) 100-ft 35mm motion-picture reel. Figure 1 shows the way in which the camera parts are lined

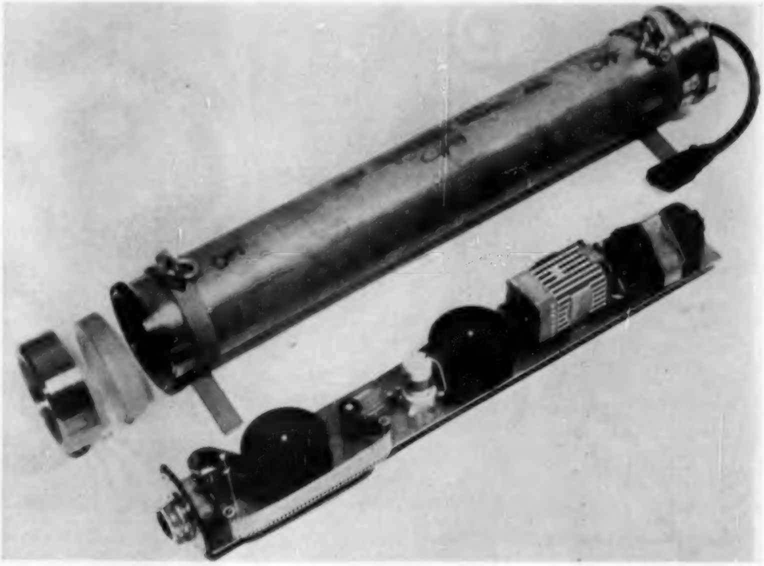

Fig. 1. Camera case with camera chassis removed from the pressure case. The reels hold 100 ft of 35mm film. An agastat was used for timing on this model.

Presented on April 21, 1955, at the Society's Convention at Chicago by Harold E. Edgerton, Dept. of Electrical Engineering, Massachusetts Institute of Technology, Cambridge 39, Mass., and Lloyd D. Hoadley, Woods Hole Oceanographic Institution, Woods Hole, Mass.
(This paper was received on February 28, 1955.)

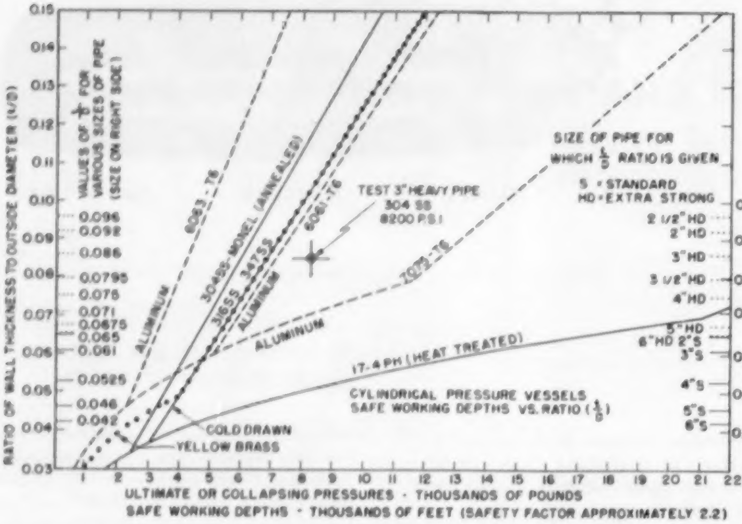

Fig. 2. Maximum pressure or depth of long cylinders as a function of the ratio of wall thickness to diameter.

up on a chassis that slips into the cylindrical housing. A 4-in. diameter is required for the film reel.

Actually, a 4-in. hole is slightly tight for the standard 100-ft reel. Some troubles were experienced in the field by film-motion stoppage at depths where the distortion of the case caused the reels to bind against the side of the case. This difficulty was solved by reducing the outside diameter of the reels in a lathe.

Figure 2 is a graph for cylindrical pressure vessels of various metals showing the maximum or collapsing pressures and the safe working depths plotted against the t/D ratio (wall thickness to outside diameter). These curves are for cylinders whose effective length is greater than six times the outside diameter; they were obtained by combining the formulas of Timoshenko, Carmen and Love and were modified by experimental data both in the laboratory and at sea.

The cylinder for the case shown in Fig. 3 is made of standard 4-in. iron pipe size, Type 304 stainless-steel pipe. The square plates welded to the tube are to facilitate mounting of the window and end-cap, and also to reduce the effective length/OD ratio, which gives a slight increase in the maximum pressure,

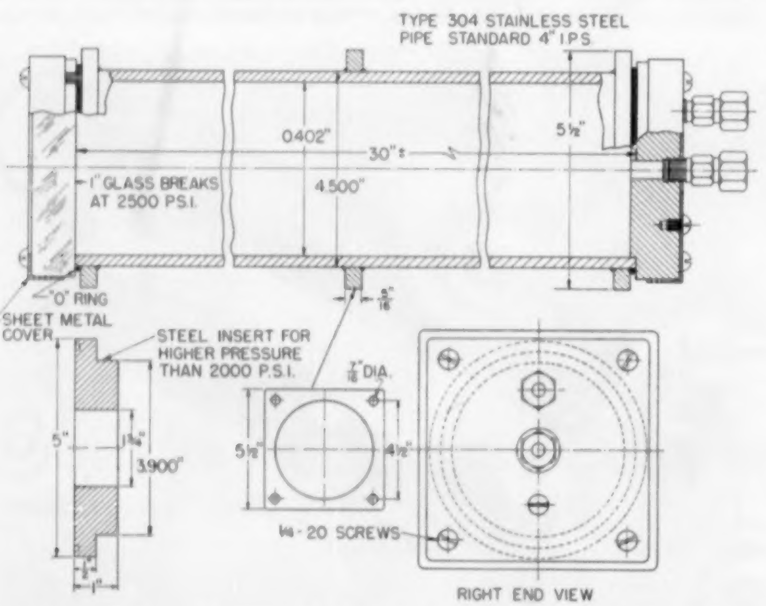

Fig. 3. Camera case, as made of 4-in. I.P.S. stainless steel with optical window and electrical connections.

and to provide better and more versatile mounting methods.

Figure 4 gives maximum pressures and safeworking pressures vs. the t/D ratio for various end closures. From this it can be seen that a 1-in. thick window with a 4-in. diameter (t/D = 0.25) will break at about 2500 psi, or approximately 1 mile. In order to use a 1-in. thick window (the maximum stock thickness of plate-glass) for greater depths and to equal the strength of the case, a stainless-steel insert or ring with a $1\frac{1}{2}$-in. effective diameter is used (t/D = 0.6667, maximum P = 17,000 theoretical); see Fig. 3. Three test points show considerable deviation from theory. See Fig. 4 for $1\frac{1}{4}$- and $1\frac{1}{2}$-in. window data.

Although regular plate-glass, which is almost optically flat, has a slight greenish tint and is not the strongest material available, it has proved to be the most satisfactory window material. Herculite, a hardened plate-glass, has strengths as much as four and five times as great as that of regular plate-glass. The slight waviness that may be introduced in the hardening process makes the seating difficult and gives highly unpredictable pressure results. These results vary from the calculated values for Herculite to values lower than for ordinary plate-glass.

Fused ground quartz has been used to gain optical qualities in special cases, but for general work the slight gain does not outweigh the cost ratio. There is no gain in strength.

End-caps are generally made of the same metal as the tube (case) and are generally thicker than the minimum to facilitate easy opening, loading and closing, and to provide ample material for the electrical connections and fittings.

Standard "O" ring seals are used on the windows and caps to provide a water- and pressure-tight unit. Single "O" rings are used for safe working pressures up to 10,000 psi. For greater pressures, double or triple rings, or double rings with leather or Teflon back-up rings are recommended. These are used for pressures up to 20,000 psi, although they usually require radial grooves similar to piston-ring grooves, and necessitate a longer tube for a given inside length.

Camera Design

Figure 1 illustrates how the various mechanical components have been mounted in line on a metal strip. The mercury switch has proved to be a most convenient method of switching while at sea. This method permits the camera to be loaded, sealed and left on the deck in the "off" position awaiting the moment of lowering, thus keeping the interior dry and clean.

Open cameras at sea can become filled with warm, humid air. As a result, when the cameras are lowered into the cold sea, the moisture condenses on the inside

of the glass window, destroying the photographic quality. Every effort must be made to keep the inside dry. For example, the camera could be flushed with dry gas before being sealed.

When a camera comes up from the sea and is cold, it should not be opened, since a layer of moisture will immediately condense over the entire interior. It is advisable to wait until the camera has warmed up, to prevent the condensation.

The film transportation has been accomplished by using two "O" rings as belts from a motor to the sprocket shaft and to the take-up reel shaft. One main sprocket is used to meter the film. A microswitch, operated by a cam on this sprocket shaft, can be used in a variety of ways, such as stopping the film motion after a frame has advanced, or flashing an electronic flash lamp at the proper moment. The take-up reel shaft is driven by a loose "O" ring belt that slips as the film builds up on the reel. The motor and attached gear reductions are attached as a unit to the camera plate. Several gear and voltage combinations can be selected from catalog combinations of the Hansen Manufacturing Co. of Princeton, Ind. The 4.5-rpm 6-v motor runs the film at a 10 to 15-sec interval/frame, which is satisfactory for many underwater assignments. At this rate the 100-ft reel is run through in about 3 hr.

Since there is no provision or necessity for focusing the camera, owing to space limitations, the optical parts have been put on an assembly that can be removed by taking out two screws. Then a ground glass can be put at the film position and the optics adjusted for maximum resolution with an enlarging eyepiece. Figure 5 shows this gate assembly with the magnifier in place over the ground glass.

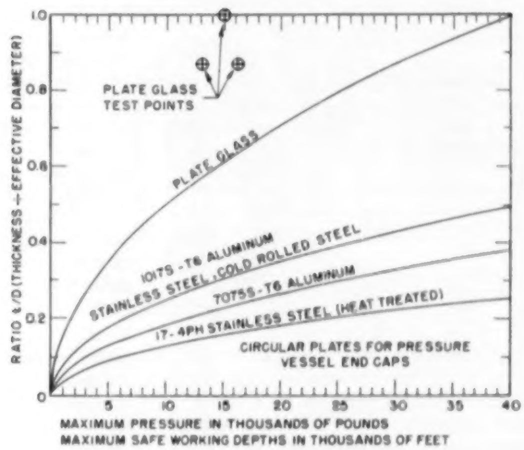

Fig. 4. Maximum pressure or depth of flat end-caps for cylinders, as a function of thickness to diameter.

Leica-type threads are used on the camera, so that Leica lenses of different focal lengths can be used.

When a shutter is required, a special Wollensak shutter with an "X" synchronizing contact can be used with a Heiland solenoid control (see Fig. 6). This special shutter has an extra arm that is connected mechanically to the shutter-blade operating ring. A spring returns the shutter to its closed position, following a pulse on the solenoid. The camera shutter can be operated from the exterior by pushbutton. Examples of such operation are cameras for use with the Bathyscaphe and with television viewing. The shutter is required for the applications to prevent exposure due to continuous lights needed for viewing. The pushbutton control enables the observer to click the photograph at the right moment, using synchronized electronic flash lighting to expose the film.

Electrical connections are brought through the cases or end-cap in gland-type fittings, as made by the Conax Mfg. Co. of 4515 Main St., Buffalo, N.Y. A

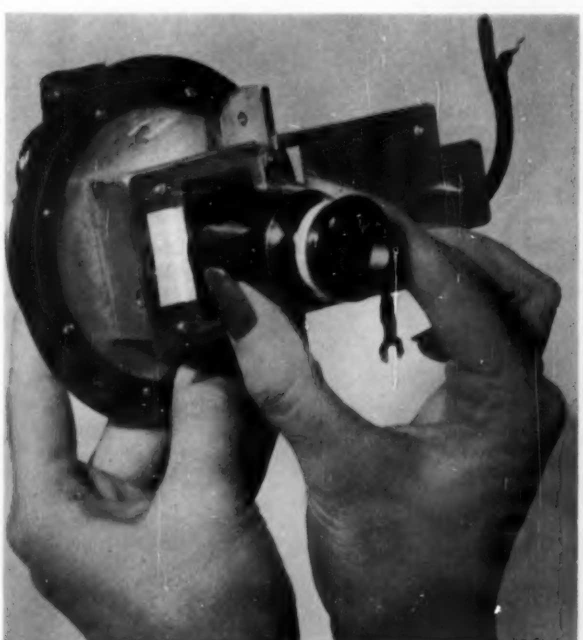

Fig. 5. Placement of a ground glass on the camera gate for alignment and focus, using an enlarging eyepiece. The front elements of the camera are separable from the camera by the removal of two screws and electrical connections.

Fig. 6. Pulse-operated shutter with "X" synchronizing contact. The solenoid connects directly to an arm on the shutter ring. Leica-type threads are used back of the shutter, so that other lens combinations without a shutter can be used.

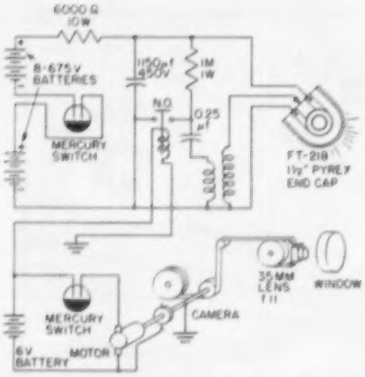

Fig. 7. Wiring diagram of a continuously recycling camera that flashes a dry-battery powered flashtube. The lamp unit is shown as Fig. 9.

solid wire with plastic insulation works very well. The use of stranded wire in the gland may result in a leak through the space between the strands if the rubber wire insulation does not completely seal.

Watertight molded plugs, made by the Joy Co., Henry W. Oliver Bldg., Pittsburgh 22, Pa., have molded ends which do not leak under pressure. Their single-prong type, 1B125F and 1B125M, and the double-prong type, 2E125F and 2E125M, have been used successfully.

Pyrex end-caps and other glass plumbing supplies of several sizes, as manufactured by the Corning Glass Works of Corning, N.Y., serve very well as covers for the flashtubes and as containers. Since the rubber gasket seldom has time to regain its original thickness or shape when the camera reaches the surface and the water pressure is released, the end-cap will be left loose. It is therefore important to use thin rubber or neoprene gaskets and to use springs under the hold-down bolts, so that leaks will not occur.

All cases should be pressure-tested with sustained pressures of 150% to 175% of the maximum expected working pressures. One must not yield to the temptation to "pop" test a case, since flaws in material or machinery may show up only under sustained stress, owing to "creep" characteristics of materials near the maximum yield stresses. Once the window has been sealed and tested it must be left undisturbed, since even the slightest piece of foreign material (dirt, chips, etc.) between the window and seat can cause premature failures. All access to the camera case should be via the metal end-cap.

On serious expeditions where a leak may occur at sea at a great distance from a base of supplies, it is very important to be prepared with spare cameras. Another precaution is to keep spare parts, such as lenses, motors, and microswitches. These are the only parts that are damaged by water. With the designs shown in this paper, a flooded camera can again be put into action quickly by changing the above-mentioned components and washing down the mechanical parts with fresh water.

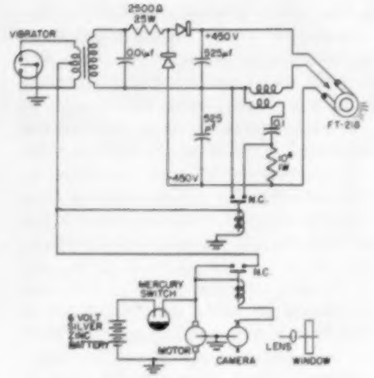

Fig. 8. Wiring diagram of a continuously recycling camera that operates both camera and flashlamp from a wet battery (6-v d-c).

Optical Correctors

When a conventional lens is used behind a plane window in an underwater camera, the image suffers distortion, especially at the edges of the frame.

James Baker has designed a two-glass corrector, which mounts back of a 35mm focal length lens. One of these was used on a camera that is now in service on Cousteau's ship, the "Calypso."

Another corrector has been designed by Thorndike (see bibliography). This is also a two-glass element, but it is placed in the water, in front of the lens and window. A corrector of this type

Fig. 9. Pyrex glass-encased flash unit of the dry-battery type with circuit similar to that shown in Fig. 7.

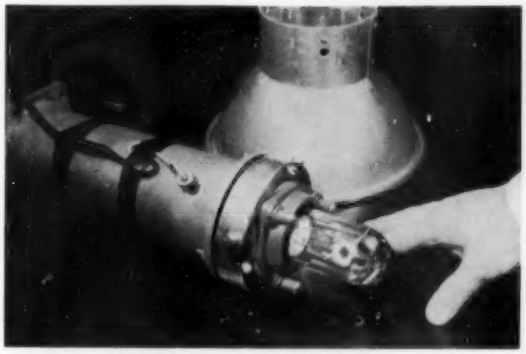

Fig. 10. Light-producing end of a 200-wsec flash unit in 3-in. heavy pipe of Type 304 stainless steel, as used on the Bathyscaphe with 24-v input.

was used on the camera installed on the exterior of the French Bathyscaphe, FNRS 3.

Electronic Flash

The flash equipment consists of standard commonly used components that are selected mainly for packaging in the cylindrical pressure cases. One major decision in the design is the type of battery to use. Both high-voltage dry batteries (see circuit Fig. 7), and wet batteries (see Fig. 8) have been used. On some occasions the wet batteries of the silver-zinc type have been employed because of the smaller volume of the battery for a given amount of wattseconds of energy storage.

Figure 9 shows a photograph of a device whose diagram is given in Fig. 7. The glass case is protected by the wood cover. Notice that the reflector is external.

The flash output varies from 50 to 200 wsec for the various units that have been used. The FT-218 (General Electric Co.) flashtube has been used at 450 v, although rated 900 v, by selecting tubes and by using a vigorous starting pulse.

When more powerful flashes are needed, multiple lighting units are supplied. For example, the French Bathyscaphe, FNRS 3, has four flash units of 200-wsec input that operate from a 24-v battery in the body of the sphere. The wiring circuit of the lamps is similar to the one shown as Fig. 8. Notice that both power and synchronism control come into the lamp case in a single wire, since the ground is common.

The case consists of 3-in. heavy pipe (iron pipe size) stainless-steel, Type 304, with a 1-in. thick end-cap. A test to destruction required 8200 psi (see test point on Fig. 2). The safe operational use was limited to 6000 psi, which corresponds to the pressures experienced by the Bathyscaphe. The light-producing end of this arrangement is shown in Fig. 10. The FT-218 tube is protected by a $1\frac{1}{2}$-in. pyrex end-cap that is modified by grinding the cast surface flat. Note the springs under the screws to maintain gasket pressure when the unit comes up from the depths. The gasket does not return to its initial thickness, because of the high pressure. The pyrex end-caps have been tested with 10,000 psi.

An experimental camera case is now being built following the designs described in this paper. The camera case will be tested to 17,000 psi, or possibly 20,000. The specifications for the deep model are:

Material: Centrifugally cast 17-4PH stainless steel, heat-treated after machining.
Inside diameter: 4.05 in.
Wall thickness: $\frac{5}{16}$-in. t/D = 0.078 max. 24,000 psi.
End-cap: 1-in. t/D = 0.25 max. 40,000 psi.
Windows: $1\frac{1}{4}$-in. thick glass.
Window diameter: $1\frac{1}{2}$-in. diameter over $1\frac{1}{2}$-in. thick steel plate.
Window: t/D = 0.833 max. 27,000 psi (theoretical); tests showed 13,000 and 16,250 psi.

Figure 12 shows the above case and the camera that goes with it.

Cameras in Use

(1) Used at W.H.O.I., summer of 1952, on the "Bear." At Honolulu by the U.S. Fish & Wildlife Service, 1952. Now at

Fig. 11. The bottom of the sea at $\frac{1}{2}$-mile depth in the Mediterranean, showing a small fish and holes in the mud. A pulsed sonar transmitter was used to indicate the position of the camera and the sea-bottom by a mercury switch, which turned the sonar off upon contact.

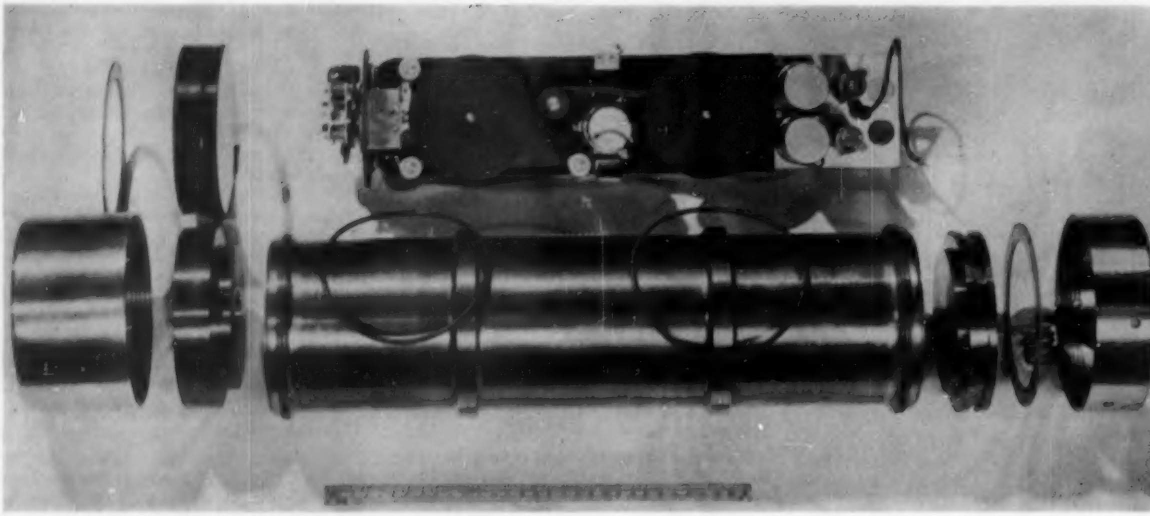

Fig. 12. A 35mm camera with 100 ft of film for the French Bathyscaphe FNRS 3. Cast 17-4PH metal cylinder with $\frac{3}{8}$-in. wall and a $1\frac{1}{4}$-in. plate-glass window was used.

W.H.O.I. on D.S.L. (Deep Scattering Layer) work; depth 2000 ft.

(2) Used by Cousteau and Edgerton on the "Calypso," summer of 1953, on D.S.L. photography in the Mediterranean off French coast; depth 2000 ft.

(3) Silhouette model used by Cousteau and Edgerton on the "Calypso," 1953, in the Mediterranean; depth 1000 ft. Used by W.H.O.I., summer 1954; now at M.I.T.

(4) In use at University of Miami, Fla., by Smith on D.S.L. and bottom photography; depth 2000 ft.

(5) Improved model used on "Calypso," summer 1954, with sonar bottom indicator; depth 6000 ft.

(6) Now in use on exterior of Bathyscaphe for pushbutton photography; depth 2000 m; Toulon, France.

(7) Now at W.H.O.I., modified with surface pushbutton control for D.S.L., with sonar viewer.

(8) Built as spare for "Calypso" effort, in case of camera loss at sea; now at M.I.T.

(9) and (10) Under construction at M.I.T. for the Bathyscaphe, with casings to withstand 4000-m depths.

Acknowledgments

Technical assistance and cooperation by Wollensak Optical Co., Sprague Electric Co., Mallory Electric Co., Hansen Motor Co., Conax Mfg. Co., General Electric Co., International Carbon Co., Wagn H. Hargbol, Precision Optics Laboratory, Parker Appliance Co., Edward M. Thorndike, James Baker, Joseph Vitka, Edo Corp., and W. G. White, Inc., are hereby gratefully acknowledged.

This project was supported by the National Geographic Society, the Woods Hole Oceanographic Institution, The Massachusetts Institute of Technology and Edgerton, Germeshausen and Grier, Inc. The Research Laboratory of Electronics' machine shop at M.I.T. constructed the cameras and greatly assisted in their design, in particular John Keefe, the foreman.

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Reliability Engineering

By C. M. RYERSON

Recent advances in the field of "reliability engineering" include specialized work in four areas: equipment reliability, component reliability, design and use aspects and reliability program administration. The present status of equipment and part reliability is reviewed, and facts are given on measurement methods and their results. Reliability calculation and prediction are touched on.

Television and motion-picture equipment engineers have for many years been derating and designing safety factors into equipment to give it long life and make it trouble-free. In a large measure efforts in this direction have been successful. In preparing this paper, the writer has asked himself how the present emphasis on reliability, initiated mainly by military difficulties, will affect the engineering picture in relation to television and motion-picture equipment. In general, there appear to be three major differences between such equipment and military equipment. First motion-picture and television equipment must not be so extreme in packaged form. Very often military equipment must be built to revolutionary forms involving very small, lightweight embodiment. Second, television and motion-picture equipment more often represents a modification of similar, older and proved equipment. When one designs a modification of existing equipment, his major problem in reliability stems from the modified portions only. The reliability problems are thus considerably less than for completely new designs. Finally, motion-picture and television equipment is generally less complex than much of the modern military equipment. The quantity of electrical parts, essentially in series service, has forced the issue of reliability with military equipment. Given parts of equal life, the effective reliable operation period is generally inversely proportional to the complexity.

There are cases, however, when these simplified generalities do not apply, and reliability becomes of major interest in providing television and motion-picture equipment. Certainly, the long-range aspects of reliability are important even in the absence of any immediate need. For example, if better circuits, more reliable components and improved techniques are developed as a result of the present reliability emphasis, these factors will assist in building better equipment and perhaps cheaper equipment in the future. Further, as problems of complex business machines and industrial process controls are faced, reliability will assume increasing importance. For these reasons, let us now look at some of the aspects of the overall reliability picture.

Presented on April 22, 1955, at the Society's Convention at Chicago by C. M. Ryerson, Reliability Administrator, Engineering Products Div., RCA Victor, Radio Corp. of America, Camden, N. J.
(This paper was received on April 18, 1955.)

Reliability as a New Field of Engineering

Recent work relating to reliability has resulted in the definition and clarification of many of its aspects. This work has emerged from a broad and indefinite area of unknowns into a definite but involved series of specialties constituting, in effect, a new field of engineering. We have found that these specialties can be developed to achieve a practical approach to reliability not otherwise possible. Four major areas are included in these specialties as shown in Table I.

Area A deals with complete equipments. Many factors bearing on reliability can be explored from the standpoint of the black box, without considering the box's contents. These factors deal with the evaluation and measurement of equipment reliability and the environmental aspects that influence it. These aspects include equipment specifications, life requirements and matters relating to performance and maintenance.

Area B deals with parts. It is recognized that equipment reliability is a direct function of the part reliability. The fundamental relationship that the reliability of equipment is inversely proportional to the complexity or the number of series-type electrical parts has been generally established. Also, it is established that the exponential failure law applies to complex electronic equipment which has been suitably "debugged." This means that good parts properly used have a constant failure rate during some normal mean life period. The implications of this fact will be enlarged upon later.

Area C deals with design and application considerations. The best parts poorly used give poor results. Likewise, proper derating of parts, and circuit design incorporating large safety factors to accommodate part deterioration, can obtain the most from mediocre parts. The best use of the best parts is, of course, the goal, and this means parts with long inherent mean life. Equipment reliability calculation and prediction come into the work of this area. These will be touched on briefly later.

The fourth and final area deals with reliability administration. Since many

Table I. Areas Constituting Specialties of Reliability Engineering.

A. *Equipment*
1. How to measure equipment reliability.
2. How good are present equipments.
3. How good should equipment be.
4. Comparison between missile reliability, fire control, communication, commercial home instrument and industrial reliability.
5. The relationship between equipment reliability and part reliability ($\lambda = \Sigma N_p \lambda_p$).

B. *Parts*
1. How to measure part reliability.
2. How good are present parts.
3. What makes parts good or bad.
4. How to get better parts.
5. How to be sure of continuing part quality.
6. How good should parts be.
7. Relation of military and functional specifications to reliability.
8. What to count on in part quality in the next two, five and ten years.

C. *Design and Application*
1. How to evaluate circuits and designs.
2. What makes good circuits.
3. Relationship between part quality and circuit application.
4. How to design for reliable new equipment.
5. Reliability calculation and prediction.

D. *Reliability Administration*
1. Field feedback of failure information.
2. Information distribution and education.
3. Coordination between engineering and production.
4. Standardization.
5. Talent and manpower considerations.
6. Public relations and promotion.
7. Finance.

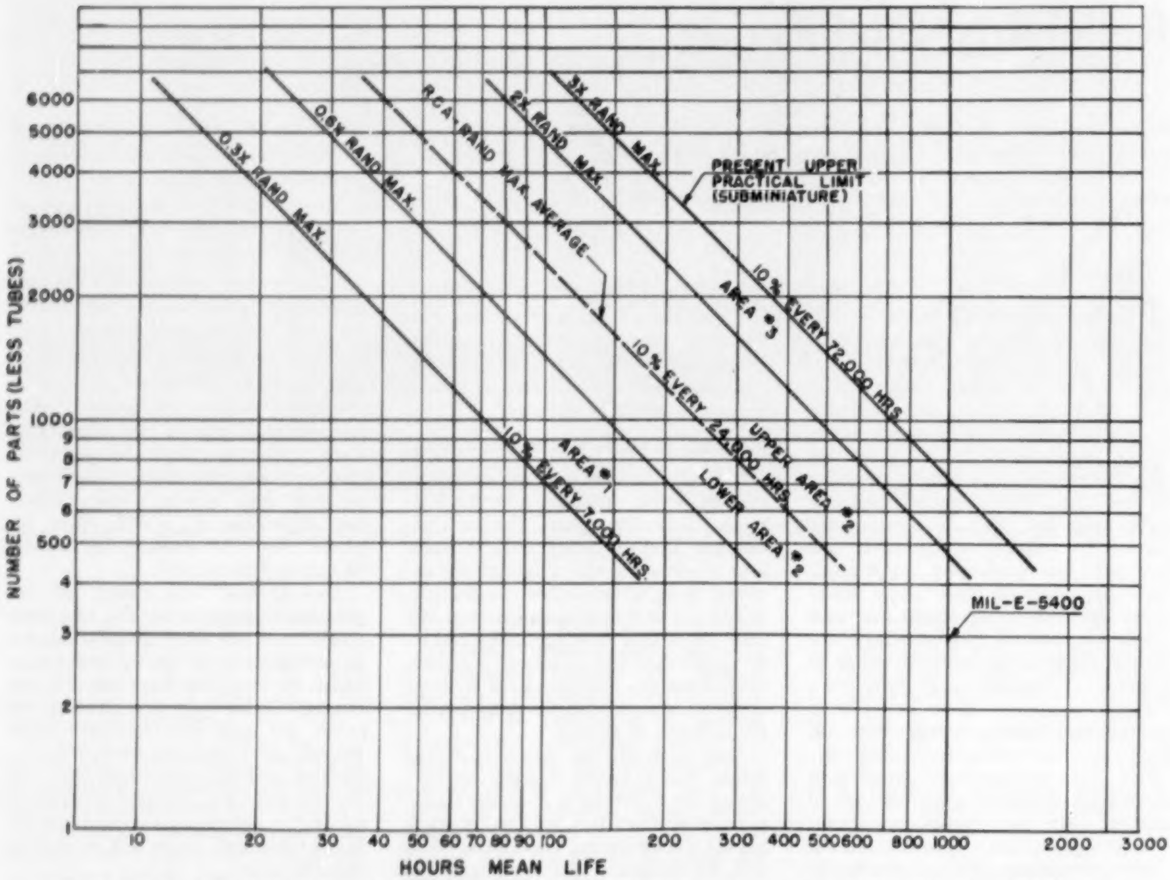


Fig. 1. Relationship of reliability and number of parts based on Rand Corp. averages and Vitro Corp. part distribution.

aspects of this phase have only academic interest for television and motion-picture engineers, it will not be dwelt upon. Let us now consider answers to some of the questions raised in each of the other areas.

Reliability Measurement

Perhaps the first essential in dealing with equipment reliability is to establish a suitable measure of reliability, or figure of merit. Of the various measures that have been used, probably the most meaningful from the engineers' viewpoint is the "mean life" and its reciprocal, the hourly failure rate. By mean life is meant the average time between failures on a probability basis. Mean life can be measured by testing equipment under controlled conditions simulating end-use environment for a period some ten times the interval between failures. Each failure is repaired, and the equipment is returned to operation. The total operating hours divided by the total failures during that interval is an effective measure of the mean life. Without going into the exponential failure law, which is the basis for this figure of merit, it suffices to say that, closely associated with the mean life, is the probability of survival of an equipment for a given length of time. The simple equation for this relationship is $P_s = e^{-t/m}$, where P_s is the probability of survival, t is the time of operation or test, and m is the mean life. This relationship applies to complete equipments and also to parts, as will be explained later.

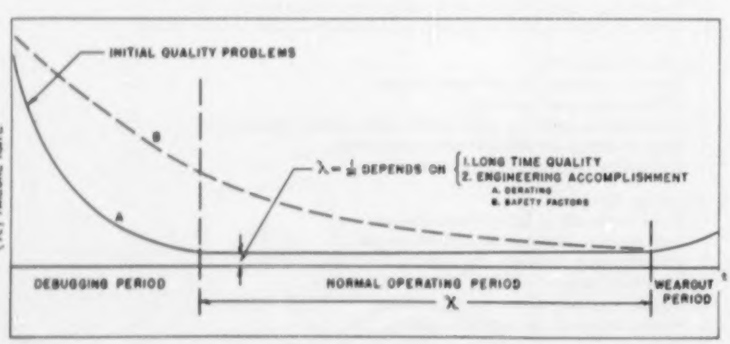


Fig. 2. Equipment life characteristic.

The Measure of Existing Equipments

In considering reliability, it is important that the type of equipment be taken into account. Reliability problems for subminiature airborne equipment are considerably different from those for standard size, permanently installed land-base equipment. Indeed, there may be several orders of magnitude difference in the difficulty of achieving similar reliability between these two types. Since subminiature equipment has existed for such a comparatively short time, many problems such as temperature dissipation and shock protection remain much less clearly resolved than similar areas of design in the older type of large-size equipment.

We have found that, for subminiature equipment, the conditions are as shown in Fig. 1. For equipment of the subminiature type and for new develop-

ments, reliability achievement in Area 1 is the result of normal design development and manufacturing without special emphasis on reliability. This chart plots the hourly mean life of equipment against the complexity of equipment. It can be seen that, in equipment containing essentially 1000 parts, a mean life of about 100 hours can be expected when little emphasis is placed on reliability. As emphasis in engineering is placed on designing better circuits, planning for better heat removal and using better parts, and as emphasis in production is placed on better quality control, vendor coordination and the procurement of better parts, equipment reliability progresses across into the upper areas.

The upper boundary of Area 3 is effectively the present upper limit of the state of the art for subminiature equipment on new developments. Equipment reliability is, of course, an integral part of system reliability. These factors, therefore, are interdependent and cannot be considered entirely separate. The Radio Corp. of America is putting considerable emphasis on system considerations as they affect equipment reliability.

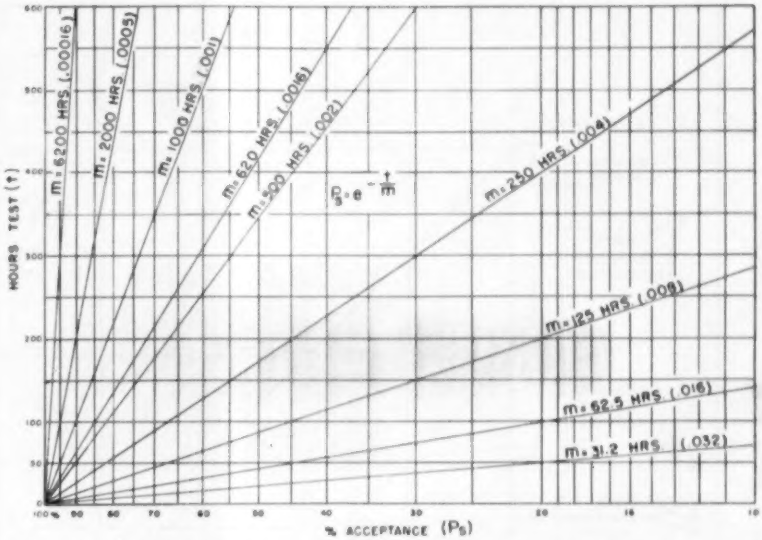


Fig. 3. Probability of survival for equipment with various mean life.

Equipment Life Characteristics

We come now to the equipment life characteristics. We have found that equipment manufactured from quality parts properly applied will provide a life characteristic similar to Curve A in Fig. 2. In other words, there is an initial debugging period during which marginal parts and incipient failures are eliminated. Following this interval, there is a normal operating period in which the equipment exhibits a fairly constant failure rate. The third and final period occurs when the normally short-life parts, such as motors and mechanical rotating equipment, start to wear out. In general, this wearout period can be postponed by preventive maintenance which will replace the early-failure components.

The high peak of the curve during initial phases of the debugging period is a function of the initial quality of the parts in the equipment. This is a factor which has been given considerable consideration, and much progress has been achieved in this field. The height of the failure rate curve during the normal operating period is a function of two major factors: (1) long-time quality and (2) engineering accomplishment. The engineering accomplishment itself is a function of two

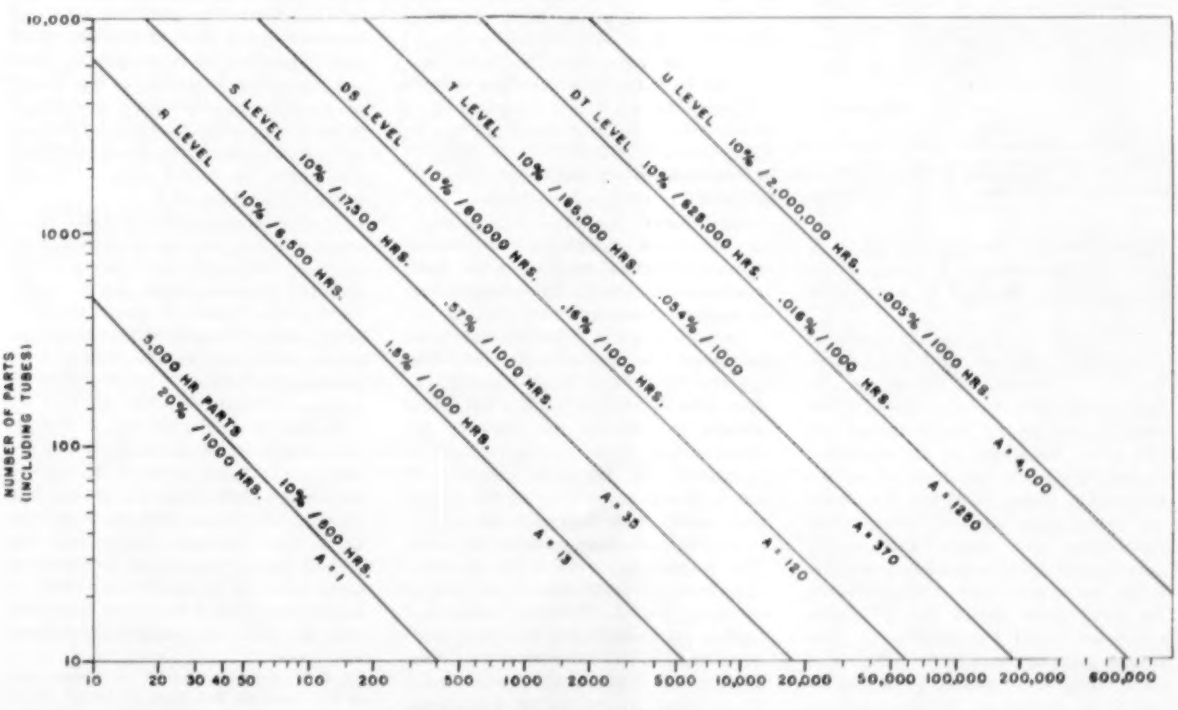


Fig. 4. Equipment reliability vs. design level.

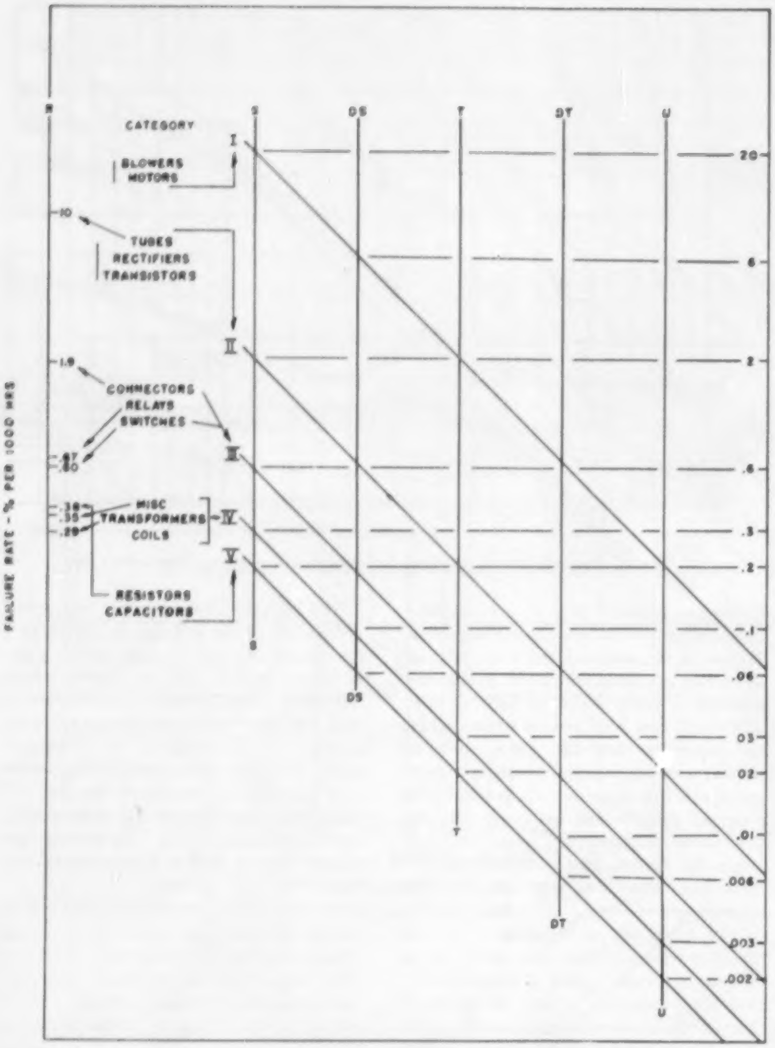


Fig. 5. Reliability levels; failure rates for five component categories in five design objective levels.

major elements, namely, derating of parts and safety factors of design. These factors will be discussed in more detail later.

The length of the normal operating period, as already mentioned, is a function of the wearout of the shorter life components. It is obvious, therefore, that safety factors in the circuit design will also affect the length of this operating period. If circuits are designed with a large safety factor, parts can deteriorate an appreciable amount before their capabilities are outside the normal operating range. Where safety factors are small, the wearout curve may commence for some parts before the debugging curve for others has leveled off. This situation or one resulting from the use of poor "long-time" quality parts can result in the equipment life characteristics resembling Curve B in Fig. 2. The tail of this curve may actually slant up at about the middle of the normal operating period on Curve A. Such equipment can never be debugged and is most unreliable.

In discussing Fig. 2, initial quality was mentioned, as was also the long-time quality. Since this dual characteristic does exist in equipment, it is important always to consider the part of the characteristic cycle during which an equipment life figure is obtained. If mean life is measured during the debugging period, an erroneous determination may reflect adversely on the equipment. The measurement might be considerably better if made during the normal operating period. The initial failures of equipment immediately following shipment come in this category if the manufacturer has shipped his product prior to a complete debugging operational cycle.

The probability of survival of equipment must be obtained by using mean life derived from equipment while operated past the debugging period. Figure 3 shows the probability of survival for equipment with varying mean life.

Part and Equipment Reliability Relationship

This brings us to a discussion of the basic relationship that exists between equipment reliability and its related part reliability. It has been shown in a Rand* report and other places in the literature that the failure rate of equipment is approximately equal to the number of parts times the failure rate of the parts, that is, $\lambda = N_p\lambda_p$.

In other words, given the failure rate for parts under the end-use conditions, it is possible to compute the equipment life. The significance of this statement needs to be emphasized. Parts have been rated in the past on their ability to perform, or not perform, under certain prescribed conditions. The element that must be added to part ratings is their failure rates with time following a debugging period and under combined conditions of environment similar to end-use. All this implies that there will probably be several reliability grades of parts in the future, each with a different price tag. The equipment price will then hinge on the level of parts required to meet the customers' need for equipment life. This situation will bring reliability engineering into its own.

An important step by RCA in the rapidly developing field of reliability engineering has been to establish standard reliability levels of design. These can be used to interpret the significance of overall equipment requirements in terms of component part reliabilities and, the converse, to determine the resultant equipment life when parts of known reliability level are used.

In establishing levels of reliability, it is important that they be consistent with the practical limitations of physical design and in line with existing accepted reliability data. Figure 4 shows six RCA design levels. This chart shows the equipment reliability versus design level, plotting the number of parts against the equipment hours mean life (m).

It can be seen from Fig. 4 that the following levels are established: The first or R level is based on the R. R. Carhart failure rate data published by Rand by assuming the survey averages were made for 24-hour operation of equipment. The S level requires an overall better equipment reliability of nearly three times the Rand level. This S level may be considered the basic or standard design level.

*R. R. Carhart, "A Survey of the Current Status of the Electronic Reliability Problem," Project Rand Research Memo RM-1131, Aug. 14, 1953, The Rand Corp., 1700 Main St., Santa Monica, Calif.

All other levels are chosen as multiples of the S level.

The DS level is essentially three times as good as the S level. This might be called a derated S level since a factor of at least three can usually be obtained in reliability when parts are suitably derated from their maximum rating. This derating is not an essential part of the DS rating, however, which can be considered an intermediate design objective for maximum part ratings.

The T level is essentially ten times better than the S level. The DT level is three times better than the T level. The U level, or ultimate design goal, is essentially ten times better than the T level and thus a factor of one hundred times better than the S level. The slight discrepancies in the values for failure rate noted on Figure 1 derive from the method of establishing the levels, which is described elsewhere.* To simplify this chart, it may be easier to remember the R level at 1.5%/1000 hr, the S level at 0.5%/1000 hr, the DS level at 0.15%/-1000 hr, the T level at 0.05%/1000 hr, the DT level at 0.015%/1000 hr, and the U level at 0.005%/1000 hr.

These approximations will not introduce serious errors in determining the proper order of magnitude. It must be remembered, however, that these are average failure rates for each level, and if it is desired to weight each type of part according to the magnitude of its usage, this average figure will not suffice. For this purpose, a breakdown of required failure rates for different types of parts for each level is required. This is shown in Fig. 5.

Figure 5 shows the six reliability levels previously mentioned, plus practical design objectives for five categories of parts. The related failure rates from the Rand figures are at the left. The components combined in each of five reliability categories are bracketed as shown. The particular combinations shown were chosen because of the related nature of the items in each category. Evidence would indicate that reliability levels can be consistent for all the components in each category. The categories are chosen to be roughly weighted in accordance with the Vitro Corp.** figures for average part distributions. From this chart, it can be seen that, although the average failure rate (equal probability of failure for each part) for the S level is 0.5%/1000 hr, the actual design goals in that level range from 20% for blowers and motors to 0.2% for resistors and capacitors. Likewise, in the U level, although the average failure rate is 0.005%/1000 hr, the actual design goals range from 0.2% to 0.002%. These ranges and goals are considered reasonable and practical.

It is emphasized that these reliability levels are design goals arbitrarily set to provide certain reliability achievement. To apply this chart for reliability analysis and prediction, the %/1000 hr failure rates must be obtained for parts under conditions similar to the maximum conditions that will exist in the end-use equipment. Also, suitable quality control in manufacture and known consistent safety factors must have been incorporated in the design. This all implies a complete knowledge and control of the maximum ambient conditions that will be applied to each part. With this knowledge and using these design levels, however, it is possible to specify the quality levels of parts that must be procured in order to obtain a specified equipment reliability. Also, the converse is possible: Given the failure rates of parts under the use conditions, it is possible to predict the ultimate reliability of the resultant equipment. Figure 6 shows typical results which can be delivered with these levels.

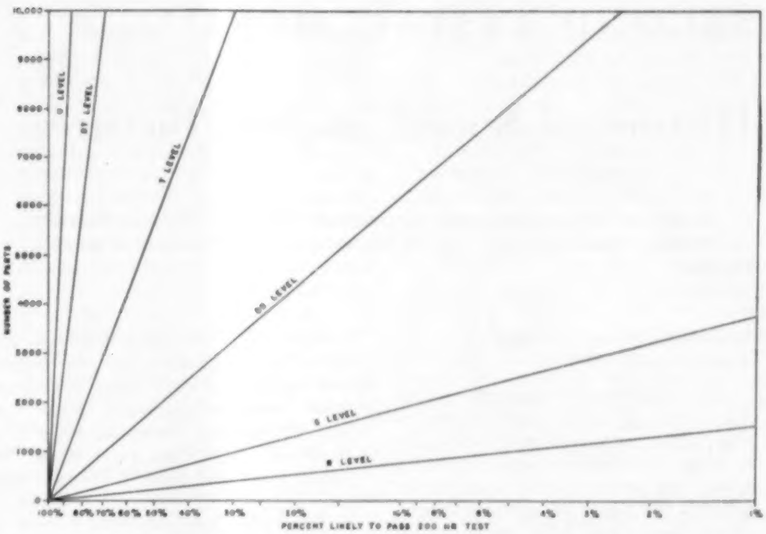


Fig. 6. Survival probability P_s, 200-hr test, vs. design level, based on Vitro Corp. distribution. $P_s = e^{-t/m}$.

Conclusion

Some of the developments in the new field of reliability engineering have been presented briefly. The effect of this new field may be to revolutionize component-part manufacture and the component-qualification field. To be sure, many changes in our design thinking and manufacturing techniques are indicated as a part of the electronics industries' task in supplying the complex but reliable equipment needed for the future.

*C. M. Ryerson, *RCA Reliability Program*, March 15, 1955. Copies of this manual may be obtained by writing the author at the address shown on the first page of this paper.

**M. M. Tall, "Component failure problems in Navy electronic equipment," Vitro Corp. of America, Silver Spring Laboratory.

SECOND INSTALLMENT

History of Sound Motion Pictures

By EDWARD W. KELLOGG

For the abstract of this paper which was presented on May 5, 1954, at the Society's Convention at Washington, D.C., see the first installment published in last month's Journal.

As one who shared in this misjudgment, I would like to suggest to readers that it is difficult today to divest oneself of the benefit of hindsight. At that time, the principal examples of sound pictures we had seen were demonstration films, very interesting to us sound engineers working on the project, but scarcely having entertainment value. None of us had seen a talking motion picture with a good story, and picture and script well designed for the purpose. When in 1927 such a picture was shown (*The Jazz Singer*) the story, the music and the dialogue were splendidly adapted to produce a fascinating picture with great emotional appeal, in which no element could have been spared without serious loss. In short, the excellence of showmanship played no small part in making it clear to everyone who saw it that the day of "Talkies" was here.

The Jazz Singer and its predecessor *Don Juan*, it might be noted, had the benefit of a newly designed loudspeaker,[67] very much superior to those used in the Western Electric 1924 demonstrations.

The Motion Picture Industry Adopts Sound

Many Commercially Unsuccessful Efforts. The historical outline with which our story began contains a very incomplete account of the many efforts to combine sound and picture, some of which attained a fair degree of technical success, elicited praise and held public interest for short periods. We mentioned the work of Edison, Lauste, Rümer, and de Forest, and might add Pathé Frères and Léon Gaumont* in France.[5] Many of these were ahead of their time, for without amplifiers, the production of adequate and natural sound was practically impossible. Even after amplifiers became available the experimenters had little better success in getting picture producers seriously interested. The article by Lovette and Watkins[48] states that by the end of 1924 practically every major producer in Hollywood had rejected Western Electric's sound-picture system.

Economic Hurdles. The same authors give such a convincing statement of the financial obstacles from the producer's standpoint that I cannot do better than quote them:

"The motion picture producers had large inventories of silent films, which had cost millions to produce. They had great numbers of actors and actresses under long term contracts, most of whom knew no dramatic technique except that of pantomime. The industry was universally equipped with stages and studios suited only to the silent film technique.

"Moreover, world-wide foreign markets had been established for silent films. To serve these markets, it was merely necessary to translate the words printed upon the film from English to any language desired. Finding stars and supporting casts who spoke the various languages of the world, or finding ways to give the illusion of their speaking them, appeared to be an insuperable task.

"The art of the silent film had attained superb quality and the public was satisfied. Why then, producers asked, should Hollywood scrap the bulk of its assets, undertake staggering conversion costs, and force upon the public a new and doubtful experimental art?

"Nor were the exhibitors equipped for sound. Many, it was argued, would not be able to meet the cost of sound picture equipment."

These obstacles would not have prevented the producers from introducing synchronized sound, had they been convinced that it would give their pictures greater appeal. A factor which many developers of sound equipment probably did not fully recognize, was that to contribute to the illusion, the sound must have a degree of naturalness far surpassing that which had sufficed for simply transmitting information, or making words understood.

How It Looked in 1926–7. To many, the silent motion picture, with its freedom of action, its settings for much of its action in natural backgrounds, was better entertainment than stage drama, and when one tried to imagine what a talking motion picture would be like, one's thoughts immediately turned to examples of theater drama. I have already quoted some of Dr. de Forest's reflections. The prevailing thought at the General Electric Co. as our system began to take shape is probably typical. Many, even of the most enthusiastic advocates of the sound-picture development were not convinced that the chief function of the synchronized sound would be to give speech to the actors in plays. The art of telling stories with pantomime only (with the help of occasional titles) had been so highly developed, that giving the actors voices seemed hardly necessary, although readily possible. Such a view was actually a very high tribute to the movie makers of the silent era. However, a very large business in synchronized sound seemed assured (even without any use of the system for dialogue) in furnishing sound effects, background music, and providing voice for lectures, speeches and travelogue commentary.

Warners and Fox Take the Step. Warner Brothers committed themselves to the adoption of sound pictures in 1926, license contract being concluded in April, followed by large investments in sound stages and equipment. In July of the same year the Fox Film Corp. became committed, forming the Fox Case Corp. which took license for the Case Laboratory developments in April, and in December from Western Electric Co. for rights to use amplifiers. Both Warners and Fox operated theater chains. With two major picture producing and exhibiting organizations definitely launched on a program of making and showing pictures, could the other great picture companies remain on the sidelines?

Large Producers Agree to Choose Same System.[6] Early in 1927 the first Fox Movietone Newsreel subjects were shown. The other picture companies must by this time have become convinced that sound pictures were inevitable, for a part, if not the whole of motion-picture entertainment. In February 1927, the "big five" — M-G-M, First National, Paramount, Universal and Producers' Distributing Corp. (or PDC), jointly asked the Hays organization to study and make recommendation as to what system should be adopted. The Movietone and Vitaphone (disk) had already

* Gaumont, in addition to many inventions and other activities, was a pioneer and successful leader in the motion-picture business, and probably came nearer to success with phonograph sound than others. See account, and references given in the Theisen history[5] from which ref. 77 is taken.

become commercial systems, Western Electric was offering a sound-on-film (light-valve) system, and General Electric had made a number of demonstrations of a variable-area system (later offered to the industry with some modifications through RCA Photophone). There had as yet been no formal standardization, and those participating in the conference probably felt some uncertainty about interchangeability of recordings. It is not strange that the picture companies thought it would be advantageous for all to adopt the same system.

By far the most ambitious demonstration of sound motion pictures that had as yet (February 1927) been witnessed was the Warner Vitaphone *Don Juan* (shown August 1926),[1, 43] with performances by noted artists and score and background music for the play by the New York Philharmonic Orchestra. And the sound quality was good. But it was a demonstration of synchronized sound, and not of sound motion-picture drama. The producers, still "on the fence," continued their "watchful waiting."

The presentation of *The Jazz Singer* in October 1927 dispelled all doubts. But whether the future lay with the disk or the film system was a question not completely settled for several years.

"Big Five" Sign Contracts with ERPI.[6] With such large producers as Warners making pictures with sound on disk and Fox with Movietone releases on film, it appeared that exhibitors might be saddled with a dual system. Perhaps it was the hope that one or the other would very soon forge ahead in the race that caused further hesitancy, but in April and May of 1928 (about six months after the showing of *The Jazz Singer*) Paramount, United Artists, M-G-M, First National, Universal and several others signed agreements with Electrical Research Products Inc. (the commercial outlet for the Western Electric systems) for licenses and recording equipment.

Getting Started.[1] There followed a period of feverish activity in erection of sound stages, and procurement and installation of recording channels and equipment. Deliveries of apparatus were far behind the desires of the customers, and there was great shortage of engineers and technicians with sound-picture background. The manufacturers and associated organizations lent or lost many of their personnel. Intensive training courses and much instructive literature alleviated the situation. The Transactions of the SMPE for the fall of 1928 are little short of an encyclopedia of sound recording and reproduction by both disk and film. To this body of literature, the engineers and processing laboratory experts from the producing companies soon began making their contributions.

Scarcely a step behind the building and equipping of recording studios was the installation of sound reproducing systems in theaters. Theater chains controlled by the picture-producing companies which had already signed contracts, used sound systems of the corresponding make, but the business of furnishing sound equipment to the great number of independent theaters was competitive between ERPI, RCA Photophone and many other suppliers. An idea of the rate of growth of the sound pictures, may be had from the following figures given in Sponable's paper.[6] At the end of 1927 there were some 157 theaters in the U.S. equipped for sound, of which 55 were for both disk and film and 102 for disk only. At the end of 1928, of the 1046 ERPI theater installations, 1032 were for disk *and* film. By the end of 1929 ERPI had equipped about 4000 theaters in the U.S. and 1200 abroad, and RCA Photophone had equipped some 1200 in the U.S. and 600 abroad, most of these being for both disk and film. The SMPE Progress Report of February 1930 states that at the time, Hollywood studios were producing only 5% silent pictures. Installations by other manufacturers brought the total number of theaters equipped for sound in the U.S. to over 8700. There were at the time 234 *different types* of theater sound equipment including the large number which were designed for disk only. At the end of 1930 there were about 13,500 theaters equipped for sound, and about 8200 not equipped, according to the SMPE Progress Report of August 1931.

Contracts for Photophone Variable-Area Recording. In 1928 RCA bought the theater chain interests of B. F. Keith and of Orpheum, and the film producing company Film Booking Office or F.B.O., and organized Radio Keith Orpheum or RKO. The new company (RKO), with Photophone equipment, and drawing heavily on the RCA group for much of its initial sound personnel, made many feature and shorter pictures, using the name Radio Pictures for its product. RCA Photophone made arrangements for license and equipment with Pathé Exchange Inc., Mack Sennett, Tiffany Stahl and with Educational Pictures Corp.

One of the first feature pictures made by Pathé was *King of Kings* directed by Cecil de Mille. The Pathé Newsreels were an important item, using a number of RCA mobile recording equipments or "sound trucks."

Disney switched to the RCA Photophone system in January 1933. Republic Pictures Inc. used the RCA system beginning October 1935 and Warner Brothers in June 1936. Columbia Pictures Inc. began May 1936 to use the RCA variable-area system for part of its operations, but continued for several years to release on variable-density.

Cinephone. The Powers Cinephone system was developed by R. R. Halpenny and William Garity for Patrick A. Powers, who financed the project. It was basically similar to the system of de Forest, with whom Powers had permissive contracts. Cinephone was put on the market in September 1929 and used for several years by Walt Disney and others.

Type of Contract. Most of the initial contracts between the equipment-manufacturing companies and the picture producers were on a lease (rather than outright sale) basis, for a stipulated term of years, with equipment servicing and engineering assistance as part of the suppliers' obligation, and royalties depending on the film footage recorded.

Evolution of a New Art, Under Difficulties.* The idea that the silent motion picture would continue to have its place in theater entertainment died hard. What *The Jazz Singer* had proved was that with a suitable story and presentation, a sound picture could have an appeal far beyond what was possible without sound. It had not proved that sound would help in *all* types of presentation. In March 1929, Fox discontinued making silent pictures. In speaking of this in his historical paper[5] of 1941, W. E. Theisen calls it a daring decision, "since a large number of the leaders of the industry still felt that sound films were only a passing fad." In "The Entertainment Value of the Sound Movie" (*Trans. SMPE*, No. 35, 1928), H. B. Franklin, President of West Coast Theatres, says: "The silent motion picture is too well established. . .to vanish because of this new development."

It took time, much work and some mistakes for the industry to learn to use sound to full advantage, and the great pressure under which writers and producers worked during the years of transition was not conducive to best results. Two quotations from 1928 papers are illuminating. In "The Public and Sound Pictures" (*Trans. SMPE*, No. 35) Wm. A. Johnson, Editor of *Motion Picture News*, speaks of the great demand for sound pictures, and says: "The present hastily turned out crop of talkies are for the most part crude and disappointing." In "Reaction of the Public to Motion Pictures with Sound" (*Trans. SMPE*, No. 35), Mordaunt Hall, motion-picture editor of the *New York Times*, describes the shortcomings of many efforts as due to stories not adapted to talkies, actors who didn't articulate, or had poor voices, and misjudgments in production.

* Many excellent discussions of the requirements for the new form of entertainment have been published. One such is Chapter IX "Comments on Production," of H. B. Franklin's *Sound Motion Pictures*.[3]

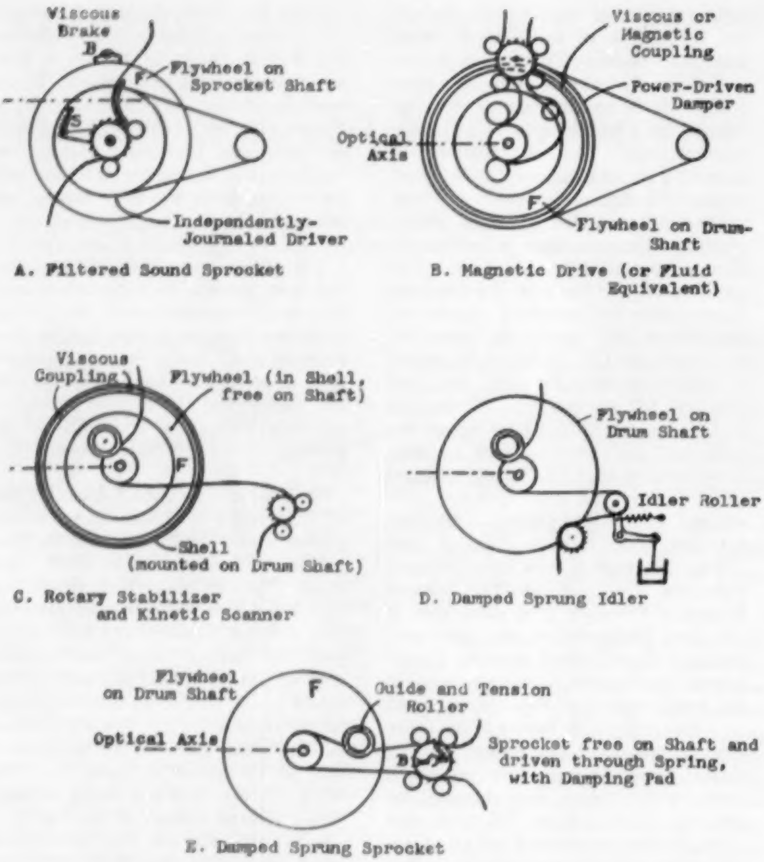


Fig. 4. Mechanical filter systems for reducing irregularities in film motion.

We tend, fortunately, to forget the troubles that are past. Still more do we forget the troubles other people had. We who took part in the development of sound equipment may be tempted to think that we made the talking picture possible. But if we give the credit they deserve to the writers, directors, actors and their bosses, and to the patient guinea pigs who bought tickets, perhaps the only bouquet left to hand ourselves is to say that our stuff was not so bad as to make the talkies impossible.

Mechanical Systems

Of all the tell-tales that remind the listener that the sound he hears is from a record and not "live pickup," the most unmistakable is that due to speed variations — known as "wow" or "flutter," and it is probably the most painful and devastating to realism. The importance of correct and constant speed was recognized by Edison and all his successors in sound recording, but standards were not very high. Phonographs sold despite their shortcomings. But sound for pictures could succeed only by providing better entertainment than silent pictures. In those systems which gained eventual acceptance by the motion picture industry, the engineers spent much effort on providing constant speed. In his story of the development of the Fox-Case system, for example, Sponable[6] tells of having to rebuild cameras, and of mounting a flywheel on the sprocket shaft and driving the combination through damped springs.

The literature dealing with speed fluctuations has been devoted largely to discussions of measures for improving the performance of recorders and reproducers in this respect.[70] Until the recent important contribution by Frank A. Comerci,[84a] such information as has been published regarding subjective thresholds or tolerances has been limited largely to continuous tones. Further systematic quantitative studies with typical program material are very desirable. There is no question however that all the present and future improvements in equipment performance are well justified in terms of more satisfying sound reproduction. Some of the more general discussions of the subject will be found in the literature.[70,79–84a]

Wow Meters. Of prime importance toward improving recording and reproducing machines is ability to measure the departures from uniform speed. One of the first such meters was built about 1928 by M. S. Mead[85] of the General Engineering Laboratory at Schenectady. It was improved by H. E. Roys and used extensively at Camden, N.J., being the basis of the flutter-measuring equipment described by Morgan and Kellogg.[86] This meter made an oscillographic recording of the fluctuations. An extremely simple and light-weight indicating flutter bridge used in RCA servicing is described in the *Journal.*[87] Flutter-measuring instruments are described by Scoville.[88] These are of the indicating type with band filters, by which flutter at different rates can be separated. Another design is described by Herrnfeld.[89] A widely used wow meter designed by U. R. Furst of Furst Electronics, Chicago, has been commercially available since 1947 or earlier.[90]

Disk System. In the disk system the change from 78 to $33\frac{1}{3}$ rpm increased the difficulties, for at the low speed even a very heavy turntable (although very helpful toward eliminating rapid flutter) was not a practical answer. A flywheel driven through springs, or what we call a "mechanical filter," was a well-known expedient, but such a system is oscillatory and will multiply rather than reduce the speed fluctuations if the disturbances are of a frequency anywhere near that of the resonance, unless the system is damped by adequate mechanical resistance.[69,70,81,91,94,100,102,104,105] The requirement that the transient disturbance of starting shall disappear in not more than one revolution is more difficult to meet with extremely large inertia. The acceptable $33\frac{1}{3}$-rpm reproducing turntables had much more inertia than had been customary for 78-rpm machines, and were driven through springs, with enough damping to reach equilibrium reasonably quickly, and dependence was not placed on making the natural frequency low in comparison with that of the slowest disturbance (once per revolution). Damping in some designs was provided by applying friction to the springs,[92,93] and in others by a viscous drag on the turntable. In either case it was essential to have high indexing accuracy in the low speed gear or worm-wheel.

For $33\frac{1}{3}$-rpm recording turntables, the Western Electric engineers went to extraordinary refinement.[70,91] On the theory that it would not be practically possible to produce gears with no eccentricity or indexing errors, they made their $33\frac{1}{3}$-rpm worm-wheel in four laminae, all cut together in one operation. Then they separated and reassembled them, each rotated 90° with respect to its neighbor. Each had its own spring connections to the turntable. Damping was by means of vanes in oil. Four vanes

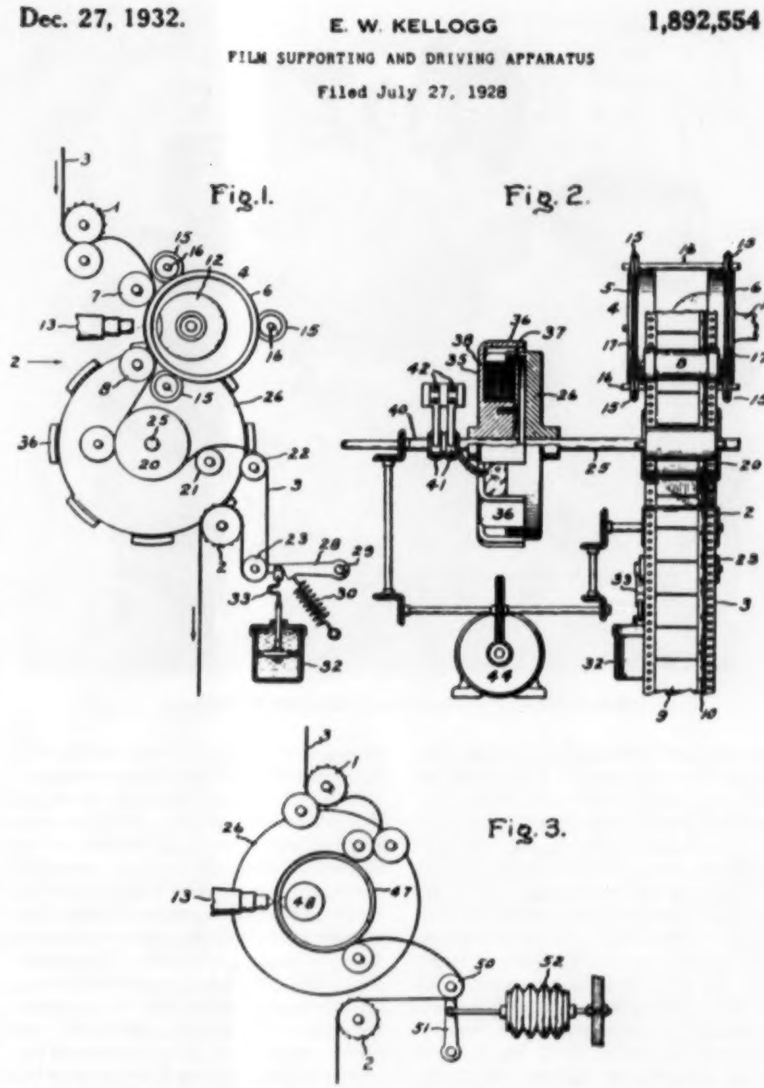
were rigidly connected to the turntable, while the pot and four other vanes were driven from the gears through a system of equalizing levers (which might be compared to whiffletrees) which imparted to the pot and its vanes a rotation which was the average of that of the four gear laminae. The effect of this was to divide by four the magnitude of each disturbance due to imperfection in the cutting of the gear, but to make it occur four times per revolution instead of once, and both of these effects are helpful toward filtering out irregularities.

Filtering Systems for Film. In a very judicial appraisal of the relative advantages of film and disk, P. H. Evans[93] speaks of the disk system as giving better speed constancy. He was of course referring to the experience up to the time of writing. There can be no question that film presents a more difficult problem. Synchronous drive and the maintenance of free loops require that it be propelled by sprockets. In the earlier systems of driving the film, it seems to have been regarded as sufficient to provide constant rotational speed for the sprocket (often called the "sound sprocket") which carries the film through the point of recording or reproduction. To obtain such constant sprocket speed it was practically necessary to use mechanical filtering to take out irregularities originating in the gearing.[4,79] But the spring-driven sprocket was very sensitive to jerks from the film, so that it was necessary to employ extra sprockets with slack film between to isolate the filtered sound sprocket. It was also necessary to have an unusual degree of precision and concentricity in the sound sprocket. (Fig. 4A).

But there remained the question of what imperfections there might be in the film perforations, or how much it had shrunk since the holes were punched. Shrinkages up to 1% were not uncommon.

A sprocket can propel a film at uniform speed only when the pitch of the teeth and that of the holes match perfectly.* Otherwise there are continual readjustments of the film on the sprocket, producing in general 96-cycle flutter, plus random small variations. A paper by Herbert Belar and myself[93] shows graphically the startling breaking up of single tones into a multiplicity of side tones by a 96-cycle speed change such as might result from a shrinkage of about $\frac{1}{2}$%.

Recorders, since they are working with fresh film, may give very little 96-cycle flutter at the sprocket. The



Film 5. Schematic representation of the magnetic drive for film motion, showing also provision for damping by use of a movable roller with dashpot.

Western Electric recorders of the earlier 1930's were designed on this basis.[4,90] The large sprocket was of precise construction and a nearly perfect fit for unshrunk film. It was on the shaft with a flywheel, and driven through damped springs. Another sprocket (unfiltered) drew the film from the magazine and resisted the pulls from the take-up magazine.

The engineers who designed the recorders supplied by RCA took no chances with sprocket teeth. In the first General Electric recording machines the film was carried past the recording light on a smooth drum (with a flywheel on its shaft) and a soft-tired pressure-roller prevented slipping.[67] Between the drum and the sprocket which fed the film through the machine at synchronous speed were flexible loops of film which (so long as they remained under sufficiently low tension to retain their flexibility) would not transmit appreciable disturbances from the sprocket to the drum. Because of uncertain shrinkage the drum must be free to choose its own speed. The simplest expedient was to let the film pull the drum, like a belt. Machines built this way worked so well at times that they delayed the effort to design something on sounder principles. My own part in the development of a better machine lay originally in the recognition that the stretch of film which pulled the drum, in combination with the inertia of the flywheel, constituted an oscillatory system, although its period varied so greatly that the irregular action did not look like that of any oscillator we were accustomed to seeing. Another trouble was that the film loop

* Sprocket propulsion of the film through the light beam has certain advantages for printers, as will be explained in the section on printer improvements. This mechanical section, however, seems the logical place for a brief review of studies by J. S. Chandler and J. G. Streiffert of the Eastman Co., directed to the reduction of sprocket-tooth flutter.

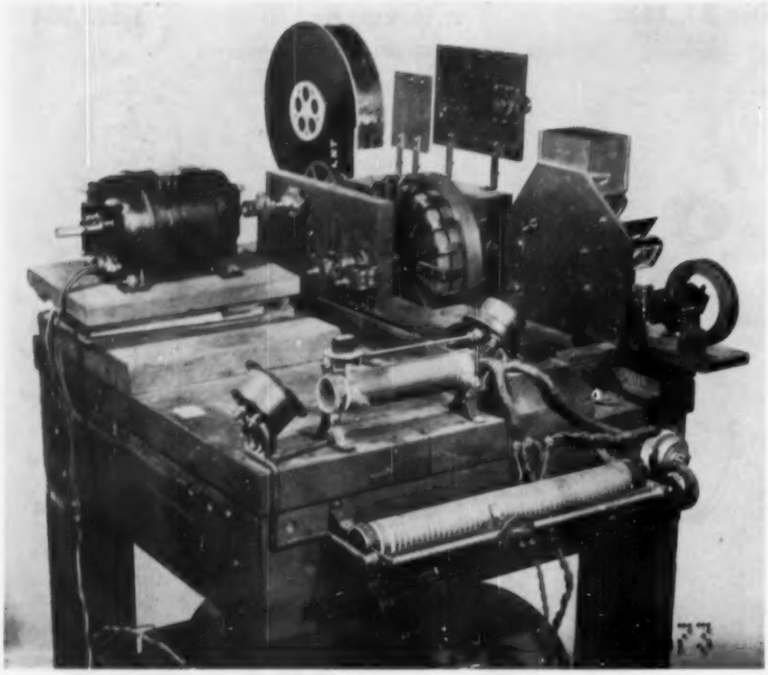


Fig. 6. Original model of magnetic-drive recorder.

was not free enough for isolating the drum. The cure for the bad effects of oscillatory action would be to provide damping. One way to provide this would be by bending the film around a flexibly supported idler roller,[106] connected to a dashpot. Another measure would be to use eddy-current damping at the flywheel by mounting a copper flange on the flywheel, spanned by a set of magnets. To use stationary magnets would provide damping but would also produce a steady drag, making a really flexible film loop impossible.[103,103a] By mounting the magnets so that they could be driven somewhat above flywheel speed, it became possible to provide a forward torque as well as damping, thereby relieving the film of all but a small part of its tension. (Figs. 4B, 5).[94–96]

The first magnetic-drive machine (an experimental model) (Fig. 6) employed both the damped idler roller and the rotating magnetic damper, but the latter was so effective that the first was superfluous. By adjusting the magnet current the film loop could be caused to run anywhere between a very slight deflection and a nearly semicircular bend. A production model (the R-4) recorder was designed in 1929 and was in production in 1930.[94] It was followed by other models (PR23 in 1933[98] and PR-31 in 1947[99]) employing the same principle.

The magnetic drive probably carried the idea of isolation of the film drum from disturbing forces farther than it has been carried in any other film-recording machine. Its extreme effectiveness as a filter system was demonstrated by Russell O. Drew and myself at the SMPE's 1940 spring convention.[96]

Although only a few were built, I should mention another recorder, the R-3,[70] designed by C. L. Heisler of the General Electric Co., which preceded the magnetic type. This had the smooth drum with flywheel to carry the film past the recording point, and the sprocket drive to hold synchronism. The drum was driven through a continuously adjustable-speed friction drive, which might be compared to a cone pulley, and the speed adjustment was automatically controlled by the length of the loop of film between the sprocket and drum, which loop was measured by the position of a movable deflecting roller.

Effect of the Tri-Ergon Patents.[35,114] Mention has been made of the development, beginning in 1918, of a sound system by Vogt, Massole and Engl, to which the name Tri-Ergon was given. They obtained very broad patents in Germany and were allowed some extremely broad claims in the United States. The patent which figured most seriously in litigation was No. 1,713,726 in which one claim covered the use of a flywheel on the shaft of the roller which carried film past the translation (recording or reproducing) point. Another claim covered carrying the film on a short roller and scanning it at the overhanging edge, and a third (based on a showing of flexibly mounted rollers pressing against and deflecting the stretches of film on either side of the drum) called for a spring-pressed roller engaging the film between the sprocket and the roller (drum). Patent attorneys in the RCA group and Western Electric felt very confident that the broad flywheel claims could be safely disregarded because anticipated in many old sound-recording and reproducing devices, but the patent departments would not approve constructions using the overhung film for scanning until after about 1930, when W. L. Douden of the RCA patent department discovered an older disclosure of the same idea in a patent application of C. A. Cawley* (to which RCA obtained rights).

Film-Transport System of Soundheads. So the first reproducing machines to be marketed avoided the overhanging film feature, and instead pulled the film through a sound gate, where the scanning light passed through it and into the photocell. Friction in the gate made this arrangement much less favorable to constant speed than the use of the overhung principle. For constancy of film speed no further measures were used than to try to provide good sprockets to pull the film through the gate, and to filter the motion of the sprocket by use of a flywheel, and driving through springs. To damp this filter, the RCA PS-1 used grease-pads acting on the flywheel (Fig. 4A) and the Western Electric used a balanced pair of oil-filled sylphon bellows which acted as a dashpot supplementing the driving springs.[53] A practical improvement over filtering the sound sprocket was to drive a heavy flywheel on the sound-sprocket shaft by multipleV belts directly from the motor, and then by gearing take from this shaft whatever power is needed to drive the projector. The heavy flywheel and tight coupling to the motor gave the sound-sprocket drive such high mechanical impedance that its speed constancy was not materially disturbed by the irregularities of the projector load.

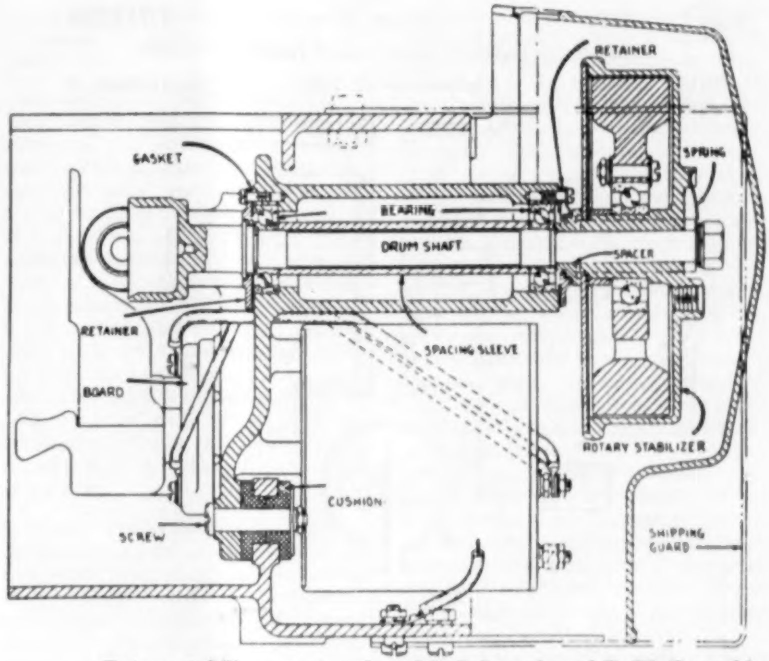
The Rotary Stabilizer. The discovery of the Cawley patent application by Douden made the RCA Patent Department consider it safe to build machines in which the reproducing light passed through the film where its edge overhung a short roller. With this privilege the way was open to make the film motion in reproducing machines comparable with that which had been attained in the magnet-drive recorder. However a less expensive construction was very desirable. The damping in the recorder was by eddy-current coupling between the flywheel and a coaxial magnet running at nearly the same

* The Cawley application had been filed Jan. 28, 1921, but had been held up on technicalities. It was put into suitable shape and issued Sept. 29, 1931 as a parent patent, No. 1,825,438, and three divisional patents, of which No. 1,825,441 contained the claims to the overhang feature.

speed. The functional equivalence of eddy-current coupling and viscous-fluid coupling was well recognized. I had tried some experiments with viscous coupling to a coaxial member which was not independently driven but was free to pick up the flywheel speed. The inertia of the viscously coupled member would tend to keep its speed constant so that a change in flywheel speed would cause relative movement and hence energy loss.[100] But I gave up in view of the feebleness of the damping I obtained.

It remained for C. R. Hanna of Westinghouse to make an analysis of the system. He showed that in order to get critical damping of the mass which is rigidly connected to the drum, the viscously coupled mass must have eight times as much moment of inertia, and the coupling coefficient must have the right value.[60] In 1932 and 1933 E. W. Reynolds and F. J. Loomis of the RCA Victor Co. in Camden did the job right.[101] The directly connected mass was an oil-tight shell of aluminum alloy inside which was a heavy cast-iron flywheel supported on a ball bearing whose friction was negligibly small in comparison with the oil coupling. Small clearance between concentric surfaces and a suitable oil gave the desired coupling. The inertia ratio was less than 8:1, but damping somewhat short of critical is satisfactory. By use of high-grade ball bearings the drum with attached stabilizer was caused to run with so little tension on the film which pulled it that the loop had plenty of flexibility for effective filtering.[102, 102a] (See Figs. 4C and 7.) The rotary stabilizer introduced in 1933 proved so satisfactory that it has been retained with little change for twenty years. A device on similar principles, called the "kinetic scanner" was used in Western Electric soundheads early in 1936[103] (Type 209).

In 1941 Alberscheim and MacKenzie[81] and Wente and Müller[104] described damped flywheels in which the entire viscously coupled mass was liquid. In order that there might be sufficient viscous resistance to movement of the liquid with respect to the container, partial obstructions were placed in the annular channel. This type of damped flywheel was used in the recorders and reproducers of the stereophonic system developed and demonstrated by the Bell Telephone Laboratories. Study has been given to the problem of finding suitable fluids. A low-temperature coefficient of viscosity is desirable, and if the entire coupled mass is liquid, high density is valuable.



Rotary stabilizer construction of F. J. Loomis and E. W. Reynolds.

Fig. 7. Cross section, showing construction of the "rotary stabilizer."

Filters Using Movable Idler Rollers. The use of this type of filter was avoided in this country because of the danger of infringement suits on the basis of either the Tri-Ergon patent (No. 1,713,726)[35] or the Poulsen and Peterson patent (No. 1,597,819). Both of these show rollers elastically pressed against the film to deflect it from a straight path and thereby provide flexibility. Neither patent shows or mentions provision for damping, and yet the great merit of such an arrangement is in the simplicity with which damping can be obtained and not in the extra flexibility, for plenty of flexibility can be had by simply freeing the film of too much tension.[102,102a] The flywheel may be solid and the arm on which the film-deflecting roller is mounted can be connected to a dashpot. (Even a cruder frictional device may give good results, but resistance of the viscous type is better.) A laboratory model of a soundhead using this type of filter was built about 1928 by the writer and performed very well, but did not receive patent approval (Fig. 4D).

After the patent obstacle to the use of the sprung-idler type of filter was ended, soundheads employing this principle were brought out by the Century Projector Corp. and the Western Electric Co.[105] and a recorder by Western Electric.[106] RCA adopted this film-motion system for 16mm machines and lightweight recorders R-32 and R-33,[107] but for 35mm soundheads continued to use the rotary stabilizer, the advantage of the movable-idler design being not so much a matter of performance as of lower manufacturing costs, an item which is contingent on schedules and tooling costs. Recently the flexibly mounted idler filter system has been utilized by RCA[108] and others[109,110] in soundheads for use with multiple magnetic soundtracks.

Filter System With Drum and Sprung Sprocket. A film-motion system developed by engineers of M-G-M is described by Wesley C. Miller.[111] Recording or reproduction takes place on a drum with solid flywheel, and the drum is driven from a sprung sprocket isolated from other sprockets by loose loops. The film passes from the sprung sprocket, around the drum and back to engage the opposite side of the sprung sprocket, and this portion of the film is maintained under tension by a roller pressing against a free span of the film. The tight film affords the required traction between film and drum. Adjustable friction pads between the sprocket and its shaft cause frictional resistance whenever the deflection of the sprocket driving springs changes, thereby damping the system.

Excellent film motion was obtained in these machines (Fig. 4E).

Minimizing Sprocket-Tooth Flutter. J. S. Chandler, in 1941[112] showed it to be possible to so shape sprocket teeth that the film speed would fluctuate between a maximum and minimum value which are the same at perfect fit and spread progressively with increasing misfit, but with a net flutter which can for a moderate range of shrinkage be quite small. However the realization of the calculated flutter values demands perfect perforation uniformity and freedom from any sticking on the teeth as the film is fed on or stripped off.

A further development in improving sprocket action is described by J. G. Streiffert.[113] The driving faces of the

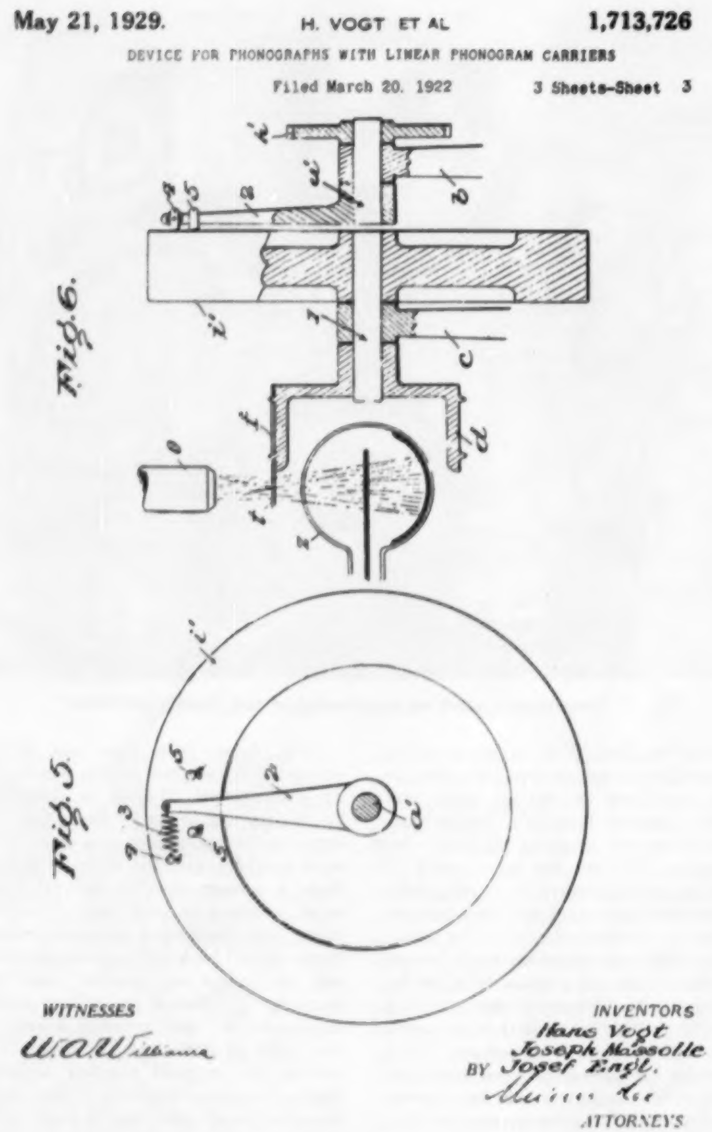


Fig. 8. Tri-Ergon showing (U. S. Pat. 1,713,726) of flexibly mounted rollers deflecting the film between sprockets and drum.

teeth are radial and the film is supported on a cylindrical surface which is slightly eccentric with respect to the sprocket. The film is fed on at a point where the teeth project only slightly above the film support, and as it travels around its arc of engagement the film gets closer to the roots of the teeth. The radius from the sprocket center to the film thus keeps decreasing, and therefore the velocity of the tooth face at the plane of the film decreases. The effect is essentially as though the tooth speed and the tooth pitch decreased correspondingly. The design is such that the tooth enters the hole with a margin of clearance and with the effective velocity (since the working radius is here near maximum) slightly greater than that of the film. The tooth face therefore gains with respect to the film, closing up the clearance, and as soon as it touches the edge of the perforation begins propelling the film. While it is doing so the next tooth is catching up. Each tooth in turn propels the film from the moment that it reaches the perforation edge until the next tooth, which at the instant is moving slightly faster, touches the edge of its perforation. Thereafter, the effective speed of this tooth, which continues to decrease, is less than that of the film, so that a gap or clearance develops between the tooth and the leading edge of the perforation. The design is such that the film is not stripped from the teeth until, in all cases, sufficient clearance has accumulated to avoid possible interference during the stripping.

Assuming that the film velocity is equal to that of the driving-tooth face at the radius where it touches the film, the film speed will fluctuate by the amount by which the effective tooth speed decreases as it travels one tooth pitch. This can be a very small change, especially if there is a large number of teeth and the eccentricity no more than needed to take care of a reasonable shrinkage range.

The region on the circumference of the sprocket where the propelling action takes place varies with the shrinkage of the film. Thus with unshrunk film the propulsion will be relatively near the place where the tooth enters the perforation, while with shrunk film it will be where the teeth are projecting farther, so that the point of contact is nearer the root of the teeth.

One way of describing the action of the system is to say that a film of any given shrinkage finds the appropriate radius where the pitch of the teeth equals the pitch of the perforations, and this is the region where propulsion takes place.

The Eastman Co. has used this system with excellent results in experimental printers. The Streiffert paper gives wowgrams of negative recordings made on such a sprocket, and also of contact prints, and for comparison wowgram (or flutter recordings) of prints made in a conventional sprocket-type printer, showing a major reduction in flutter with the new sprocket.

Litigation. Despite the efforts to avoid infringement of such claims of Tri-Ergon patent No. 1,713,726* as appeared to have any likelihood of being held valid, the American Tri-Ergon Corp. brought suit against Altoona Publix Theatres Inc., who were using an RCA Photophone (PS-1) projector attachment or soundhead. The case was tried at Scranton, Pa., in the U.S. District Court for the Middle District. The apparatus had been sold with a guarantee against patent liability, and the suit was defended by RCA, Electrical Research Products Inc. giving technical assistance in the defense. The court ruled (Feb. 10, 1933) that seven of the claims were valid and infringed. The case was appealed and reviewed by the U.S. Circuit Court of Appeals for the third circuit (in Philadelphia), which affirmed (June 13, 1934) the findings of the lower court. The defendents then appealed to the U.S. Supreme Court, which at first refused to review the case, but finally decided to do so, and on Mar. 4, 1935, ruled that the seven claims in the suit were all invalid (294 US 477).[114]

* This patent, issued May 21, 1929, was filed in the U.S. Mar. 20, 1922, and had a German filing date of Mar. 24, 1921.

This removed the threat to the equipment manufacturers of what might have been almost crippling damages, for had the findings of the lower courts been sustained the plaintiffs would have been in a position to bring suits for damages for infringement by most of the recording and reproducing equipment in this country, and covering a period of over five years.

The American Tri-Ergon Corp. applied on Feb. 18, 1937, for a reissue patent with modified claims, and this was granted Jan. 11, 1938, as Re. No. 20,621. On Oct. 25, 1946, RCA reached an agreement with American Tri-Ergon Corp. whereby it was granted rights under both the original and reissue patents.

Two other patents placed restrictions on the film-motion systems which American engineers could safely employ, namely Poulsen and Peterson No. 1,597,819 (filed July 9, 1924, and issued Aug. 31, 1926) and Poulsen No. 2,006,719 (filed Germany Sept. 1, 1930, and U. S. Aug. 19, 1931, and issued July 2, 1935). These patents to Danish inventors were owned by British Acoustic Films Ltd., which brought infringement suits against RCA Mfg. Co. and against Electrical Research Products Inc. The trial (in Wilmington, Del.) was before the U.S. District Court for the District of Delaware (43 USP-Q69). The arrangement shown in the patent comprised a drum propelled by the film, the film being passed around a flexibly mounted idler roller. Some of the claims in suit described the invention as "means contacting the film for increasing its flexibility." The apparatus in suit was the RCA PS-24 (rotary stabilizer type), which has no flexibly mounted roller, but was alleged to have the equivalent in that the film loop was so formed by the fixed rollers as to be very flexible. The court ruled Sept. 22, 1939, that the claims in suit were not infringed and not valid (the flexibly mounted idler having been disclosed in the earlier Tri-Ergon patent).

Plaintiffs appealed and the case was reviewed by the Circuit Court of Appeals of the Third Circuit which affirmed the findings of the lower court (46USP-Q107, June 27, 1940).

To forestall possible future trouble RCA obtained rights under these patents by agreement with British Acoustic Films Ltd., Dec. 21, 1944.

Immediate Requirements for Sound

Our historical story thus far has been confined almost entirely to the three fundamental elements, sound pickup (or microphone), a recording and reproducing system and loudspeakers. These represented the difficult phases of the problem, but before sound could become commercial certain items of equipment had to be made available and techniques established. Before discussing the advances in the art that followed commercialization, we shall mention some of these items.

Standard Track Position and Width.[115] Agreement between the makers of variable-width and variable-density systems was reached in 1928. The reproducing light spot must cover more than the extreme width of the clear area of a variable-area track, with both ends on black areas, but should fall entirely within the width of a variable-density track. This requirement is met with margins of safety, by recording density tracks 0.100 in. wide, while the scanning spot is 0.084 in. long. The modulated area of a variable-width track is limited to 0.071 in. with the black parts extending to the 0.100-in. width. The track center line is to be 0.243 in. ± 0.002 in. from the edge of the film.

Printers. Continuous contact printers previously used for pictures only could be adapted to sound by providing masks by which light could be confined to either the picture or the soundtrack area. Except for certain newsreel negatives, the sound and picture were on separate negatives, so that the print film had to be run through the printer twice. Even when the sound was on the same negative as the picture, the offset was not usually the required 14.5-in. and independent light controls were needed. Combination printers were soon developed which were essentially two printers in cascade, so that the print was complete with one passage through the machine.[116–120]

Bloops. The development engineer can overlook many defects so long as he knows their cause and that the apparatus he is testing is not at fault, but before sound pictures could be shown the public, these faults had to be corrected. The noise which a splice makes as it passes through the scanning beam can be made almost inaudible by cutting off the light gradually instead of suddenly. This was accomplished at first by painting a black spot with sloping edges over the splice. Later, black patches which could be quickly cemented in place where the splice crosses the sound track were made available. These are called "bloops." They are of trapezoid shape, masking off the entire sound track for a distance sufficient safely to cover the splice and with end slopes designed to change the light gradually enough to keep the noise just below noticeability at normal gain settings. The design of bloops is discussed in several papers.[121–123] To prevent a disturbance due to a printed-through negative splice, Sponable[124] described a punch which made a hole in the negative, resulting in a suitably-shaped black spot on the print.

Electrical blooping of splices in negatives has come into extensive use. When a negative splice goes through the printer an auxiliary light exposes (through the base) a suitable area of the print film, an edge notch or other means being employed to control the blooping light.

Lewin (Apr. 1947)[124a] describes a system of silencing splices in re-recording positives in which the output is momentarily suppressed in response to a punched hole.

Blimps.[125] Cameras which were entirely satisfactory for silent pictures were much too noisy for making sound pictures. Much quieter cameras were developed eventually,[126–128] but for immediate requirements it was necessary to reduce the noise radiated by existing cameras by building shells around them with thick layers of sound-absorbing material. These were called "blimps," or sometimes "bungalows." To smother the sound and still give access for the necessary operations was enough to tax the skill and ingenuity of the designer. Even with the quieter cameras it is still common to resort to partial or complete sound-insulating housing.

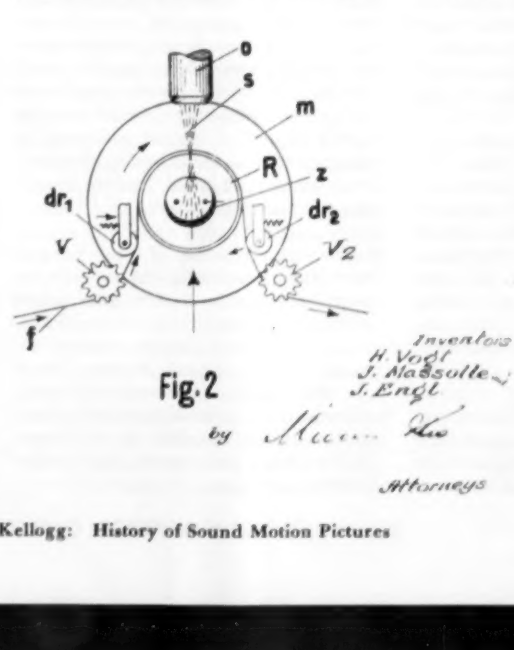


Fig. 9. Tri-Ergon showing of filtered sound-sprocket and overhanging sound-track.

Sound Stages.[129,130] The requirement of freedom from noise necessitated the building of sound stages in which extreme measures were taken to exclude noise of outside origin. Many of these had double concrete walls and double floors, with sound absorbing material between, the inner walls and floor being supported on cushion mounts to prevent transmission of earth tremors. The roof and ceiling structures were designed on the same principle.

The high absorption (or short reverberation time) desirable for recording purposes helped control noises originating inside, but so far as possible all sources of noise were eliminated. Noisy arc lights gave way to incandescent or other quiet lamps, and all mechanisms were made to operate as noiselessly as possible. Ventilating systems required extreme measures.

In recording dialogue, the better the suppression of general room reverberation, the farther (within limits) from the action can the microphone be placed, thus affording more uniform coverage and making it easier to keep the microphone out of the field of the camera. If some echoes are wanted the "set" can frequently be designed to produce enough. Artificial reverberation using echo chambers in the recording channel or equivalent devices has many applications.

In contrast to the requirements for speech, the recording of music calls in general for rooms with considerable reverberation.[131–133]

Theater Acoustical Treatment.[134,135] The acoustical treatment of auditoriums has probably received more study than any other phase of architectural acoustics, perhaps because the desired characteristics are most difficult to attain. The reverberation must be sufficient to make music pleasing and to help equalize sound intensity in the various parts of the space, but must be short enough not appreciably to impair clarity of speech. A high order of directivity in the loudspeakers plus application of absorbent materials to any large surfaces toward which they are directed has helped with this part of the problem.

In general every theater or auditorium, many of which were built before the era of sound pictures, presents its own problems and calls for individual study. For new theaters there is optimum shape to consider as well as best distribution of absorption. The multiple loudspeaker systems (discussed later) besides making new effects possible have given the acoustical designer somewhat more freedom.

Booms and Dollies. In order that microphones might be suspended as near the action as might be wanted but just above the field of the camera, and in order that their positions might be readily changed, microphone booms of various types came quickly into use. The more elaborate of these were much like derricks on platforms, with rubber-tired wheels on which they could be moved quickly and almost noiselessly.

Similarly, rubber-tired, battery-operated camera dollies enabled the cameraman rapidly and quietly to change the position or height of his camera.

Equipment of the kind just described underwent improvements through the years, but the main features were available from the start of commercial sound pictures.

Monitoring and Level Control.[136–139] Another line of equipment the essentials of which were made available as soon as recording machines, and which has been improved from time to time, was that providing for monitoring and level controls and (especially in re-recording operations) for adjusting the relative levels from several sources, or "mixing." Volume indicators[140,141] of several types were in use in broadcasting stations, and the design of mixing controls was well established.

The man responsible for recording judged the quality by means of a monitoring loudspeaker. He could check quality as represented by the current supplied to the light modulator, or by means of a photocell, in terms of the light reaching the film.[1,64,204] In the case of the RCA Photophone system there was a card on which the modulator projected a light-spot, the movements of which showed the amplitude being recorded on the sound track.[142]

It was for a time held by some that the monitoring speaker should be of the same type as a theater speaker, but high-quality monitoring speakers of the direct-radiator type were soon made available, and these were much better suited to the small rooms where the controls were located. In terms of frequency range covered, the cabinet-type monitoring speakers kept pace with the improvements in theater speakers (see section on loudspeakers). High-quality headphones have also found wide use in monitoring.[143,211] Whatever type of listening device is used, it should obviously be designed to give the recordist about the same range and tonal balance that a theater patron would get.

Screens. Our sense of the direction from which sounds come is too keen for us to be fooled by loudspeakers placed alongside or above the screen. Sound must come from directly behind the screen to give a good illusion. This is one of the lessons that was learned early. Screens of the types developed for silent pictures caused excessive loss and distortion if placed between the loudspeaker and the audience.

Mention has been made of a sound-transmitting screen developed by E. I. Sponable in 1927.[6] One of the first papers in the SMPE *Journal* dealing with screens for sound pictures was that in 1930 by H. F. Hopkins.[144] His curves of measured transmission indicate good results with screens having perforations whose total area is 4% or 5% of the screen area, and show definite advantage in a thin (0.013-in.) screen rather than a thicker (0.030-in.) material. With such screens the loss of brightness need be no greater than the proportion of the area taken out by the holes. Allotment of about 8% of the area to holes has been common, for example about 40 holes of 0.050-in. diameter per square inch.[145]

Processing, Variable-Density.[146] In the story of the work at Western Electric and Bell Laboratories I said that it was recognized by Wente and by MacKenzie that for the correct, or linear, relation between negative exposure and print transmission, the product of the negative and print gamma* should equal unity.† This is in accordance with principles set forth in early SMPE papers by L. A. Jones[63] and by A. C. Hardy.[61] Since practice in making pictures had been to develop the print to a gamma of approximately two, and both sound and picture would receive identical development, the sound negative should be developed to a gamma of about 0.5 or slightly higher. Picture-positive film was used for a number of years for sound negatives. Developers of the types used for picture negatives tend to give low contrast and fine grain, and the use of such developers helped to give the desired low value of gamma for the sound negatives.[147,148] MacKenzie[64] gives some information about the harmonic distortion which results from departures from the unity product, and thus gives an indication of tolerances with respect to development.

With the advent of sound, with its requirement for more strict control of development, control by use of sensitometric test strips, and by specified time, temperature and developer formulas[149–152] supplanted dependence on visual judgments of operators, where that practice had prevailed.[153,154] Maintenance of developer activity received much attention,[155–158] and stop baths assumed increased importance.[159,160] Rack-and-tank methods, where these had been followed,

* Gamma is the slope of the straight portion of a curve plotted with density $\left(\text{or log of } \frac{1}{\text{transmission}}\right)$ as ordinates and log exposure as abscissae. This is known as the Hürter and Driffield, or H & D curve. Gamma product is a measure of overall contrast as compared with that in the original exposure.

† In practice, because of some loss of contrast due to stray light in optical systems, best results with pictures had been found with somewhat higher gamma product.

gave way to continuous machine processing.[161–163]

How generally the distinctions between specular and diffuse density,[164] and between exposure modulation by varying time (light valve) and varying intensity (as by glow lamp)[165] were understood at first is a question, but these points were well covered in the literature. The Eastman Capstaff Densitometer,[166] which was developed primarily for measuring picture negatives for contact printing, reads diffuse densities. This would be appropriate for measuring the densities of sound negatives for use in contact printers, but not for densities of soundtrack prints, for it is the specularly transmitted light which reaches the photocell in a reproducer.

The widely used Eastman IIb Sensitometer, brought out about 1932,[167] which gives an accurately standardized series of test exposures in the form of a step tablet with exposure time increasing in the ratio $\sqrt{2}$ per step, and ranging from about 0.004 sec to 4 sec, has been of utmost value in maintaining controls. However, it does not simulate soundtrack recording conditions, where the intensity is extremely high and the time for average exposure was approximately 1/18000 sec (1/36000 sec with a later light-valve system and in present practice about 1/90000 sec) and still shorter for low exposures. The 1934 paper by Jones and Webb[165] gives an indication of the magnitude of the error. The Eastman Sensitometer on the other hand gives exposures which approximate sufficiently well those which a print receives, and are thus suitable for determining gamma of contact prints. For many purposes it has been satisfactory to draw conclusions by applying correction factors, if needed, to the readings of these instruments.

In the course of a few years densitometers employing photocells were developed which had the advantages of greater accuracy and much faster operation than the Capstaff visual-balance type.[168–173] For exposing sound negatives for sensitometry purposes, the light valve itself, with suitable calibration, can be used. The subject is again discussed under "Intermodulation Test."

While the conditions for low distortion were to keep both negative and positive exposures on the straight parts of the H & D characteristics, studies reported in 1931 by D. MacKenzie[172a] showed that low distortion was still possible while using the "toe" range of both films ("toe recording") or that of the positive only ("composite"). Toe recording using positive stock for the sound negative might, if the recording-system light was limited, be preferable to resorting to faster and coarser-grained recording stock. In the case of single-film systems (sound recorded on the picture negative) where the development of both the negative and positive soundtracks is fixed by picture requirements, MacKenzie found that the composite system offered best promise of low distortion. Both the toe and composite systems give higher output than a classical or straight-line system, but poorer signal-to-noise ratios.

It took a number of years to bring about the full transformation from the methods (depending much on visual judgments) which had been employed for making silent pictures, to the close controls and scientific precision needed for satisfactory and consistent sound. The constant and close checking of every element exerted a pressure for improvement along the whole front, including the manufacture of the film, in which departures from uniformity were quickly detected. The story is interestingly told by J. I. Crabtree.[146] An early account is given by J. W. Coffman.[153]

Processing, Variable-Area. Since the ideal variable-area track is part clear and part black with a sharp boundary between, there is no question of preserving correct shades of gray, but in general the higher the contrast (or gamma product) the better. As in the case of variable-density tracks it must be assumed that the print development will be that which is wanted for the picture, and that has been taken in general to give a gamma of about 2.0. Variable-area negatives as well as the prints are processed in high-contrast developers. The variable-area system is noncritical with respect to gamma product but, for a given positive emulsion and processing, there is for any given negative a best setting of printer light.

A comprehensive study of available sound-recording films and their processing was published by Jones and Sandvik.[173] Another study was made by J. A. Maurer.[174] From his curves it appeared that negative densities of 1.3 or higher were desirable, and the prints which gave maximum outputs were the ones having densities (in the dark areas) about equal to those of the negatives from which they were made. This held true for negative densities ranging from 0.6 to 1.3 and higher. The maxima however were very broad.

In November 1931, Dimmick[175] reported the results of a series of determinations of conditions for maximum output from a 6000-cycle recording, using Eastman positive 1301 for negatives and prints, and 4, 6, 8 and 10 min in D-16 developer. The study covered an adequate range of the four variables — negative (recording) exposure, negative development or gamma, printing exposure and print development. The results showed that wide ranges in each of the variables could be used with comparatively small loss of output, but for any negative there was a print density at which output was greatest. It made comparatively small difference (except near the extremes) whether a given density of either negative or print was reached with small exposure and longer development or more exposure and less development, but in general the maxima were broader with the higher values of gamma, especially that of the print. The two highest gamma values in the series, 2 and 2.18 of both negative and print, in general gave best results, with negative densities (measured in the black areas) in the range 1.5 to 2, and print densities a little less in each case than that of the negative.

While maximum high-frequency output is of less consequence than avoidance of cross-modulation (which is discussed in the section on distortion) it is of interest that recommended practices based on the test just described come very close to those found to be best in later experience and after current testing methods had become established. The cross-modulation test did not come into general use until 1938.[176]

For a number of years a print density of 1.4 or slightly higher, with appropriate corresponding negative density, was taken as a practical objective. As galvanometers and optical systems were improved and finer grain films came into use, the tendency was toward higher densities for both negatives and prints, especially for the negatives.

Evolution in a Growing Industry

Greatly Expanded Developmental Activities. The development work prior to commercialization of sound was carried on largely in laboratories supported by manufacturers of supplies or equipment, or in independent laboratories, and it was done on the basis of hope for returns which might be realized either through patent royalties or through sales of equipment or both.

Once sound pictures began to be made and shown, developmental work was on a different basis. Research and investigations of numerous incompletely solved problems took on rather the character of plowing in profits, with greatly increased total expenditures for research and participation by all the major picture-producing organizations.

Of all of the problems, the most fundamental and greatest in magnitude was learning how to use sound pictures, or the evolution of a new art. This is discussed by J. E. Abbott.[177] The expression "growing pains" aptly describes the less successful phase of this evolution. Capacity for readjustment is one of the qualities of greatness in individuals and in organizations, and the motion-picture industry came through splendidly.

When any industry becomes large, and especially if its requirements are as diverse as those of sound pictures, it provides a market for numerous special-

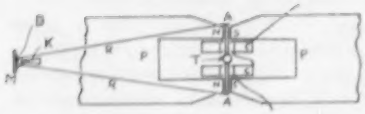


Fig. 10. Arrangement employed by G. L. Dimmick in 1929 galvanometer, for multiplying the rotation of the mirror.

ties and services. Many of these requirements are met by comparatively small organizations and others by branches of companies having many other activities and products. A few such items will serve to illustrate: special lamps, arc carbons, screens, cameras, acoustic treatment materials and service, chemicals, printers, testing equipment and studio apparatus. Many important improvements and contributions to technical advances are due to those who develop and supply such auxiliary equipment.

Mingled with the natural rivalry between picture producers has been a spirit of cooperation and sharing of experience and knowledge which has greatly accelerated progress. In 1930 this society began issuing the monthly *Journal* instead of the quarterly *Transactions*, an appropriate step to accommodate the rapidily expanding literature of sound-picture technology, covering almost every phase of the making and showing of motion pictures. The Academy of Motion Picture Arts and Sciences also played an important part in promoting interchange of information. Engineers and technicians from the sound-picture laboratories have reported experiences with various problems related to processing and controls and to sensitometry, while film and photographic suppliers have spared no efforts to enable those using their product to get the best possible results.

So many have been the contributions to the art and science along these lines, that I find it quite beyond my ability to do more than pay this general tribute and to mention a very few developments which have seemed to me to be of outstanding importance. I trust that I may be forgiven for showing partiality to the types of development with which I am most familiar, and also if I unjustly fail to mention many important advances.

Some of the Improvements After 1930

Galvanometers for Variable-Area Recording. The galvanometers used in the first variable-area recorders supplied by RCA Photophone were practically standard oscillograph vibrators, as these had been built at General Electric. They were oil-immersed and responded well up to 5000 cycles or above. An improved smaller model was brought out in 1930,[177] completely sealed instead of having an open oil well and with no external adjustments. This used molybdenum ribbon (much stronger than the bronze) and was tuned to about 6000 cycles.

When recording was started at the RKO studios in Hollywood, one of the men from the General Engineering Laboratory who had had much experience with oscillographs, F. B. Card, joined the RKO staff. The RKO engineers soon decided that their sound would be better if the frequency range were extended. The ribbons of the oscillographs had been of phosphor-bronze. A small supply of duralumin ribbon was obtained, and with this Card succeeded in re-stringing the RKO galvanometers, with sufficient tension to tune them to nearly 9000 cycles. A thinner damping fluid was then appropriate, a change almost necessary to realize the benefits of the higher natural frequency.

G. L. Dimmick came to the General Electric Co. in 1929, and one of his first projects was the development of a new galvanometer which was promptly used in newsreel equipment.[178] He used a magnetic driving system of the balanced rocking armature type and by an ingenious mechanical arrangement, shown in Fig. 10, made his mirror rotate through about ten times the angle of the armature. The important advantage of this galvanometer was that the mirror was about ten times the area of that of the previous galvanometers. A few years later Dimmick designed a new galvanometer on the same principle (Fig. 11) but improved in numerous details.[148,179,180] This became the RCA Photophone standard for all photographic recording. These galvanometers were tuned to about 9000 cycles. Damping was by means of a block of rubber, the action of which was analogous to that of the rubber line of H. C. Harrison,[*,49] but since it had to work only at high frequency it could be of quite small dimensions. Dimmick found that he could increase the effectiveness of such damping blocks by incorporating tungsten powder in the rubber to increase its density (Fig. 12).

* See June *Journal*, p. 296, third col.

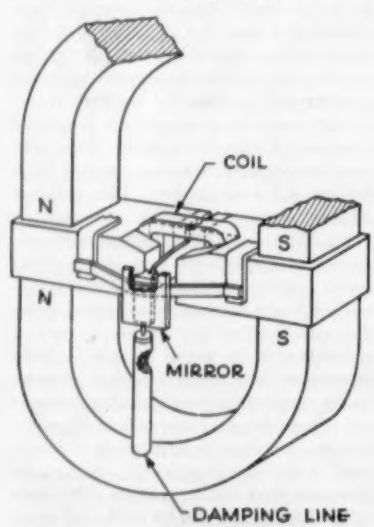


Fig. 12. Construction of RCA recording galvanometer (shown in section in Fig. 11).

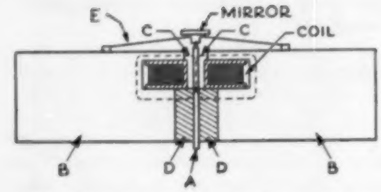


Fig. 11. Cross section of improved recording galvanometer, G. L. Dimmick. A—armature; B,B—pole pieces; C,C—working air gaps; D,D—nonmagnetic spacers; E—tensioned bronze ribbon.

Further improvements in the galvanometer were reported by Dimmick in July 1947.[181] By the substitution of better magnetic materials he was able to reduce hysteresis almost to zero, to increase the sensitivity, and to avoid a slight saturation effect which had been present in the previous design.

A More Efficient and Versatile Optical System. In order that the galvanometer in one of our experimental optical systems might be closer to the slit, and thus send more light through it, I arranged a galvanometer to work on its side, so that it would move the light spot up and down across, instead of parallel to, the slit. I used a light spot with a sloping edge at an acute angle such that the change from zero to full-length slit illumination was accomplished with a movement equal to only one-fourth of the slit length.[*,182] Dimmick improved on this by making the light spot symmetrical with respect to middle of the slit, and having two sloping edges (see Fig. 13, and in Fig. 14 compare C with B). An advantage of the transverse-movement system was that it became very simple, by changing the masks which were imaged on the slit, to produce a variety of tracks which had their special applications.[148,180,183,184]

The combination of larger mirror and reduced distance between galvanometer and slit practically eliminated the diffraction trouble that had, with the small mirrors, impaired the formation of clean, sharp, high-contrast images at the plane of the slit.

Ground-Noise Reduction—GNR.[185] Scratches and dirt on film and graininess of emulsion cause a background noise

* All galvanometers have practical limits to the angle through which they can swing the light beam. And the required light spot movement sets a minimum to the distance between galvanometer and slit. The light which a galvanometer can send through the slit is proportional to the mirror area and the inverse square of its distance from the slit, up to the point at which the objective lens is "filled."

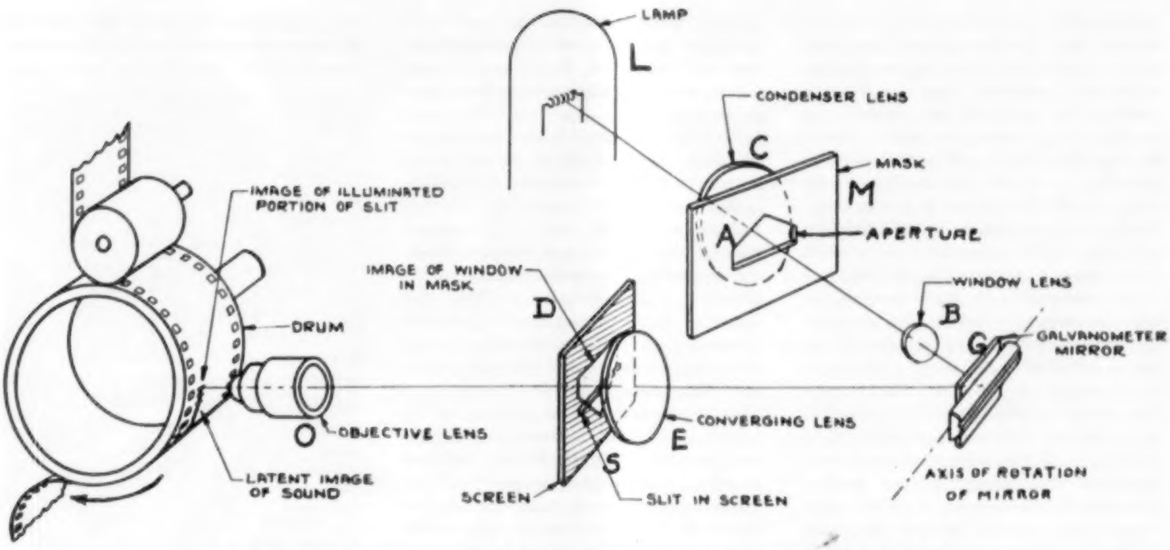


Fig. 13. Variable-area recording optical system. (Lens B images A on slit-plate D.)

which is particularly conspicuous when the modulation is low. The noise is reduced by reducing the transmitted light. At the same time, for a given modulation level there is no need for the average transmission to be more than about half the maximum. The noise may thus be reduced when the reduction is most needed, by decreasing the average light when the level of the recorded sound is low. This can be accomplished by biasing the light modulator toward zero, and then using a current derived by rectifying some of the modulation current to increase the mean light transmission when this is needed. The reduced transmission when the modulation is low means a darker track in a variable-density system, or a narrower clear area in a variable-area system, and in either case the noise is reduced. The early patent on this idea was to E. Gerlach.[186] This was assigned to Siemens & Halske, but to the best of my knowledge it occurred independently to L. T. Robinson in Schenectady and C. R. Hanna at Westinghouse,[187] and a system applicable to light valves was developed at Bell Laboratories.[188] The first trials at Schenectady with variable-area tracks did not indicate an impressively large reduction of noise, and there was an objection (in the case of the earlier, unilateral, variable-area tracks) in that the bias threw all of the low-level modulation over to one edge of the track, where many reproducing light beams were of reduced intensity. The project was revived by Hugh McDowell of RKO who got around the objection by screening off the surplus light by means of a shutter instead of biasing the galvanometer.[189] This method and the results obtained were reported to the Academy of Motion Picture Arts and Sciences by Townsend, McDowell and Clark in 1930.[190] Thereafter a commercial form of shutter was designed[191] and ground-noise reduction became standard in the RCA system (Fig. 15).

With the introduction slightly later of the symmetrical track, the objection just mentioned to depending on galvanometer bias instead of a shutter no longer applied, but there was still some danger of saturating the galvanometer. Therefore a double-vane shutter was developed to mask down the light from both sides.[192]

The Bell Laboratories system is described by Silent and Frayne.[193] In the variable-density system there is no objection to accomplishing the result by biasing the valve.

In case of a sudden increase in modulation level the rectified current would change so rapidly as to cause an audible sound. The current for the shutter or for bias is therefore passed through a filter which reduces the rate of change. Limiting the speed with which the average light can increase means some clipping of the first few modulation peaks.

The light valve is a very low impedance device, and since the bias current may have to be sustained for consider-

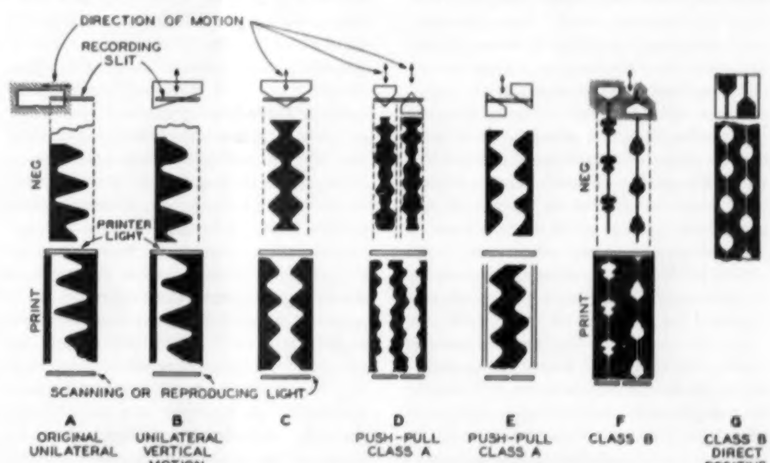


Fig. 14. Variation types of area soundtracks, and light-spot shapes which produce them.

Fig. 15. Soundtrack produced by McDowell ground-noise reduction shutter.

able periods of time transformers cannot be used for impedance match coupling to the output tube of the ground-noise reduction amplifier. In the system most widely used with light valves the modulation current is rectified, passed through the timing filter, and used to modulate a 20,000-cycle oscillator, the output of which is amplified and rectified for supply to the valve. The design of the timing filter is much simpler when it can operate at interstage impedance.[193]

As compared with variable-area, the variable-density system is characterized by ground noise which is less in the nature of "ticks" and "pops" and more a continuous hiss. Another difference is that in the density system the noise falls more rapidly with reduced light transmission, so that a given amount of noise reduction is obtained with a smaller change in transmission. The continuous hiss type of noise is especially noticeable if it comes and goes, which changing bias causes it to do. This is often called the "hush-hush" effect, and becomes noticeable if the valve opening does not immediately fall when the modulation drops to a low level. At the same time the fact that smaller changes in transmission suffice to control the ground noise makes it possible to change transmission (or bias) more quickly without causing "thump." The filters for density systems are therefore designed for much faster timing than those of area systems, particularly in closing down when modulation falls.

While clipping of initial modulation peaks is a less serious problem in density than in area recording (because of faster opening and larger margin) engineers working with both systems have given much study to minimizing such clipping. Increased margin will decrease the frequency of occurrence of clipping, but this would be at the price of more noise. In all systems, opening (increasing light) is about as fast as it can be made without becoming audible, while the closing is much slower so that very brief reductions in level will not produce incessant closing and opening.[194]

A nonlinear characteristic has been given to RCA ground-noise reduction amplifiers, which causes the opening, as a function of modulation amplitude, to rise more steeply at first and then more slowly.[195] Relatively low-level modulation is then sufficient to cause an increase in margin and thus reduce subsequent clipping. It is when the modulation is nearly zero that close margin is urgent.

Certain characteristics of speech sounds have an important bearing on the design of ground-noise reduction systems. The positive pressure peaks are higher than the negative, and it is important to maintain correct polarity from microphone to valve, or to shutter and galvanometer.[190,195] R. O. Drew and I made an investigation to determine how often speech sounds build up rapidly.[196] Instances in which maximum amplitude was reached in less than three or four waves (voice fundamental) were surprisingly rare.

The ideal solution to the problem of avoiding initial clipping would be to anticipate increases in sound level. This is discussed by J. G. Frayne.[197]

Anticipation by use of a second microphone was used experimentally in the stereophonic system described in the October 1941 *Journal* (p. 351) for operation of the compressor.[309a] A system employing a 14-msec electrical delay network is described (March 1950) by Whitney and Thatcher.[198]

When reported it had been in use for over a year by Sound Services Inc. with very favorable results. Besides reduced clipping, advantage was taken of the system to increase ground-noise reduction in density recordings by 5 db, and in area recordings to work with a bias line only 1 to $1\frac{1}{2}$ mils wide. A low-distortion network good to 8000 cycles necessarily employs many sections (several hundred). Cost is probably the reason that this expedient has not been widely employed. A direct-positive variable-area recording system with the anticipation effect provided by means of an auxiliary exposure was designed and demonstrated by Dimmick and Blaney and has been used in the Warners' studios.[199]

In the re-recording operation anticipation should be a simple matter, involving only a double reproducing system (with scanning points a fraction of an inch apart) with separate amplifiers.* Mueller and Groves (June 1949)[200] mention use of this system at Warners. I understand however that little advantage has been taken of this possibility, presumably on account of costs. The explanation is probably that when initial clipping occurs in a well adjusted re-recording system, there was probably also some at the same spots in the original recording and the possible gain from anticipation in the re-recording operation is hard to detect. If clipping, in systems using ground-noise reduction, causes an appreciable impairment to sound quality, the ideal solution is to use for original recording a system whose ground noise is inherently so low that it needs no such expedient, and then introduce the ground-noise reduction when re-recording to the photographic tracks. Similar considerations apply to the use of compressors. Among the systems which in more or less measure meet this specification are Class B area recording, wide-track push-pull (with fine-grain film and fast-acting noise reduction) direct positives with the auxiliary exposing light,[199] and direct-playback disks. A real answer to this problem seems to have come in the recent adoption of magnetic recording.†[200, 352–366]

Pre- and Post-Equalization. The practice of electrically exaggerating the high-frequency components in recording, as compared with the low-frequency components, in order to compensate for inevitable losses, began early in the recording of sound. Studies of the distribution of energy in program material had indicated that this could be done without resulting in overloads in the high-frequency end of the scale. A large amount of high-frequency pre-emphasis had been employed in cutting transcription disk records. In film records as well as disk records, ground noise can be made less noticeable by decreasing the gain at high frequency. Therefore, in addition to such relative attenuation of high-frequency sounds as was caused by the imperfections of reproducing systems and loudspeakers, the practice became prevalent of producing a drooping characteristic in the electrical circuits.

In order that all films might have good balance in all theaters, a committee of the Academy of Motion Picture Arts and Sciences made recommendations for a standard reproducing characteristic.[201] With such a standard adopted, the producers of sound pictures would have incentive to use recording characteristics which would give good balance when their films were played in a theater with the typical or standard reproducing characteristic.

The problem is discussed by J. K. Hilliard[202,203] and by Morgan and Loye.[204]

Better Lamps. Among the lamps used in the late 1920's for recording were some of the ribbon-filament type. These were ideal from the standpoint of uniformity, but required an inconveniently large current (18 amp) and did not have as long life at a given temperature as was obtainable with lamps of the helical-filament type. A series of lamps for sound recording and reproduction was made available by the lamp companies. The filaments were close-wound helices, of relatively heavy tungsten wire, and to permit operation at high temperatures with satisfactory life, the pressure of the inert gas (argon) with which the bulbs were filled was increased above that employed in lamps from which less intensity was required.

In the series of lamps described by F. E. Carlson of General Electric in 1939[205] the recording lamps were rated as operating at above 3100 K (color temperature) which is several hundred degrees higher than that of common

* In a set-up for mixing numerous sounds, it would for practical purposes be sufficient to equip only the dialogue film-phonograph with double scanner and amplifier.

† Some experimenting has been done with a double magnetic pickup for anticipation. Cross-talk between the two heads was a problem. The difficulties will undoubtedly soon be worked out.

incandescent lamps. Somewhat later, krypton-filled lamps were introduced, permitting still higher temperatures. The krypton, being heavier, more effectively retards evaporation of tungsten. (See the section on basic inventions.)

The light from a helical filament varies somewhat, depending on the angle from which the lamp is viewed. At the suggestion of L. T. Sachtleben of RCA, the helix of the lamp used in the variable-area recordings was curved, the convex side being presented toward the lenses. The helix with the curved axis gives definitely better uniformity.[183,205,206a]

Improvements in Light-Valves and Density Optical Systems. In June 1932 Shea, Herriott and Goehner[66] described the development of improved duralumin ribbon (stronger and with straighter edges) and better methods of adjusting and anchoring the ribbons at the ends of the free span. The new anchoring system practically eliminated the frictional hysteresis which had been found in the earlier design, thus reducing waveform distortion and making for greater stability. Stability became increasingly important as the mean spacing between the two ribbons in the valve was reduced. The ground-noise reduction system called for reducing the ribbon spacing when the modulation was low, and when it was found possible in view of required exposures to reduce the unbiased spacing from 0.002 in. to 0.001 in. this was done, while still keeping the optical reduction from valve to film at 2:1.

At high frequency and high modulation, the images of the ribbon edges move with velocities comparable with the speed of film travel. This results in a waveshape distortion which would convert a sine wave into a saw-tooth wave. Fortunately such a combination of high frequency and amplitude is not often encountered in program material, and the harmonics generated would probably not be reproduced, nor noticed if they were. However, it is desirable to minimize this "ribbon-velocity" distortion, and the reduced slit width helps in that respect and also in giving better resolution or high-frequency response.

In order that harmful effects (harm to sound quality if not to the ribbons themselves) might not result when the modulation current drives the ribbons to the point of touching or hitting each other (light-valve "clash") light valves have been built with the ribbons slightly offset, or in two planes.[207] There appears to have been difference of opinion about the necessity of this precaution. It should be remembered that in a density system the downward light modulation normally stops considerably short of zero, to avoid photographic nonlinearity. In other words touching of the ribbons would represent considerable overload. The two-plane design of valve has become generally standard for variable-density recording.

The optics of light-valve recording systems[207] have been modified by the addition of a small horizontal cylindrical lens close to the film, which results in greater optical reduction between valve and film and therefore a narrower image (0.0002 in.). This makes for improved high-frequency recording and for further reduction of ribbon-velocity distortion. One of the factors which has made the narrower image possible without sacrificing exposure is that new lamps of higher intensity have become available.

Light-valve optics have been adapted to making variable-area tracks, for example as used in the stereophonic system described in 1941.[208] The valve is turned with the ribbons vertical, or parallel to direction of film travel. The lens system, which employs cylinders, magnifies the ribbon motion ten to one. This means that the lens must be close to the ribbons, hence with little depth of focus. Therefore in this application the ribbons are in the same plane, and an electrical current-limiting expedient prevents clash.[209]

A strong magnetic field is advantageous for the sake of sensitivity and damping. In the design described by Wente and Biddulph[208] an air gap flux density of 32,000 gauss is attained, an achievement which testifies to the excellence of the permanent magnet materials and the high flux capacity of the pole-piece material. There is some further discussion of light valves in the section on variable density vs. variable area.

Microphones. While condenser microphones had excellent characteristics they were more expensive and required more servicing than magnetic microphones, and it was practically necessary to provide a stage of amplification close to the microphone. On the other hand, the electrical impedance of a magnetic microphone is such that a transformer may be used if wanted, and the output transmitted at a convenient impedance. A magnetic microphone of the flexibly mounted rigid-diaphram, moving-coil type is described by Jones and Giles in December 1931.[210,211] It is a pressure-type (rather than velocity or pressure-gradient) microphone. Damping is obtained by flow of air when the diaphram vibrates, back and forth between two cavities, through passages which are of such small dimensions as to make air viscosity effective in dissipating energy.

In June 1931 H. F. Olson described the velocity microphone,[212] consisting of a ribbon of very thin aluminum (0.0001 in.) in a magnetic field between pole pieces which are adjacent to the edges of the ribbon, so that when the ribbon moves in a direction normal to its surface a voltage is induced in the ribbon. A transformer is used to step up this voltage, which is then applied to the grid of an amplifier tube. Transverse corrugations are formed in the ribbon, which prevent it from curling and give it lengthwise flexibility. It is mounted under only such tension as is needed to keep it between the pole pieces. Olson shows that theoretically such a microphone should give uniform frequency response, and that it should have a polar directivity curve like a figure 8 (cosine law), the directivity being the same throughout the frequency range. Experimental results are also given confirming the theory. The velocity of movement of the ribbon is proportional to the velocity of air movement, so that it is often called a "velocity microphone."

Since a microphone of this type responds less and less as the direction of the sound departs from normal, it picks up much less reverberation (random in direction) than a nondirectional microphone having the same sensitivity for sound of normal incidence. The ratio of direct to reverberant sound in many cases sets the limit to how far from the source the microphone can be placed, and under such circumstances a ribbon microphone can get satisfactory pickup some 70% farther from the source than a nondirectional microphone, such as one of the pressure type.[213] Advantage has been taken of the directional characteristics of the ribbon microphone to exclude certain sounds or disturbances (for example camera noise), for it is deaf to sounds originating in the plane of the ribbon.

If the output of a pressure microphone is combined in correct phase and amount with that of a velocity microphone, the combination becomes unidirectional, having a cardioid-shaped directivity curve. It has a dead-spot 180° from the direction of maximum sensitivity. The forward directivity is much less sharp than that of a velocity microphone, and such a unidirectional microphone is better suited for picking up sound over a wide angle, as for example from a large orchestra. The cardioid directivity pattern has the same advantage as the figure 8 pattern in picking up less noise from random directions than a nondirectional microphone.

Before making a unidirectional microphone, Olson worked out an arrangement for converting a velocity microphone into a pressure microphone. He placed close behind the ribbon a combination shield and absorber consisting of an open-ended tube of the same cross-sectional area as the active area of ribbon. He distributed through the tube tufts of absorbent fiber. The length of the tube was made sufficient to dissipate wave energy. The impedance of the mouth of the tube then becomes equal to that of so much free air (to plane

waves) but air in which there is no other sound to react on the ribbon. The ribbon is then actuated only by the pressure on the exposed side.[214]

Having successfully made this conversion, Olson applied the same treatment to only one half of the length of the ribbon, leaving the other half to act as a bidirectional velocity microphone, and the combination has the cardioid directional characteristics.[215]

Bell Laboratory engineers also developed bidirectional or velocity microphones, and unidirectional types, but differing from the Olson type in employing a second microphone more nearly like their standard pressure microphone. The unit and its applications were discussed by Marshall and Harry in September 1939.[216]

All studios use directional microphones for situations where the maximum ratio of direct to random sound is wanted.

Loudspeakers[4,26,73,222]

Single Range Loudspeakers. For several years after the industry had adopted sound the theater loudspeakers were of the kinds already mentioned, (1) the directional baffle-type, using a coil-driven cone, much like those used in direct radiator speakers, with a short, straight-axis exponential horn of large throat area, and (2) those using long exponential horns[217,218] with small throats, and coil-driven metal diaphragms. In view of their length the horns were coiled or otherwise bent to a form which took up less space.

Multi-Range Loudspeakers and Improved Single-Range Speakers. The idea of providing separate devices to radiate high and low frequencies is undoubtedly of early origin. When practically all radiators had strong fundamental resonances, the double or triple unit could spread the range of reasonably high response over a wider frequency band. With the advent of coil-driven, untuned diaphragms, resort to separate radiators was a measure for improving efficiency, in that the design did not have to be a compromise between what was best for low and for high frequencies. A triple-horn speaker designed with special consideration to efficiency and load capacity was advocated and demonstrated by C. R. Hanna of Westinghouse in 1927.[219]

However theater speakers of the single-unit type were so far improved (by the coil-driven unit of Wente and Thuras in 1926,[57] and by the adoption of directive baffles for the GE-RCA cone-type speakers in 1929) that they handled quite well the frequency range then obtainable from film or disk.

As recording improved, the benefits from extending the loudspeaker range became more noticeable. After various improvements in the recording system including the new galvanometer, the symmetrical track, ground-noise reduction (by galvanometer bias), ribbon microphone for sound pickup, and a film-phonograph using the magnetic drive, Dimmick and Belar gave a demonstration of extended frequency range at the SMPE 1932 Spring Convention.[179] They did not resort to two-way (divided-range) speakers, for the straight-axis, directional baffle units, which had 6-in. cone diaphragms with aluminum voice-coils, had good response even at 10,000 cycles. The range was extended downward (to 60 cycles) by using slow expansion exponential horns (of the large-throat or directional-baffle type) 10 ft long, with mouth openings 75 in. square.

Multi-Range Speakers of Bell Telephone Laboratories. A divided-range speaker system was used by H. A. Frederick in the demonstrations of vertically cut disk records in the fall of 1931.[220] The high-frequency units were of the type described by Bostwick in the October 1930 *Journal of the Acoustical Society of America*, and in the May 1931 *SMPE Journal*.[221] These were equipped with small horns better to load the diaphragms. The low-frequency units were of the direct-radiator or flat-baffle type, using (as I recall it) approximately 12-in. diameter dynamic cone units,[38] a number of units being distributed over a large baffle. A curve indicates a response within ±5 db from 50 to 10,000 cycles.

A triple-range system is described by Flannagan, Wolf and Jones,[222] whose review of the development of theater loudspeakers is comprehensive and of much interest. The system is also discussed by Maxfield and Flannagan in the January 1936 *Journal*.[222a] The mid-range units were essentially like the previous single-range speakers, using the Western Electric No. 555 driver units. The radiators for the high-frequency range (3,000–13,000) were the same as used in the Frederick demonstrations. The authors state that for the range below 300 cycles large coil-driven conical diaphragms in a large flat baffle gave better results than designs using horns.

In April 1933 the Bell Telephone Laboratories gave a demonstration of reproduction of orchestra music in "*auditory perspective*,"[223,224] the orchestra being in Philadelphia and the reproduction in Constitution Hall in Washington, D.C. Three microphones picked up the music at three well-separated positions, and at the other end the independently transmitted and amplified currents were supplied to three correspondingly placed loudspeakers.

In this demonstration no recording and reproduction entered to affect frequency range, and it was essential for the purpose to provide abundant sound power and frequency range. A dual-range system was decided on.

The low-frequency unit was designed to work from 40 to 300 cycles, and consisted in a large-diaphragm, moving-coil unit, working into the 8-in. diameter throat of a horn which expanded exponentially to a mouth 60 in. square in a total length of approximately 10 ft.

The high-frequency driver unit, which covers the range 300 to 13,000 cycles is shown in cross section as Fig. 10 in the Flannagan, Wolf and Jones paper.[222] Particular attention is given in the design to the air space and passageways leading from the diaphragm surface into the horn or group of horns.

If a single straight-axis exponential horn is used, the tones of highest frequency are radiated in a direction close to the axis, while those of lower frequency are spread through much larger angles. This defect is avoided by dividing the total cross section of the passage into a number of smaller passages each of which is a small exponential horn. In this case there were sixteen horns for each driver. These are nested with their mouths adjacent and with their axes pointed in different directions to cover a total angle of about 30° vertically and horizontally. Since the horns are of equal length, the waves, whatever their frequency, unite at the ends of the horns to form a practically continuous spherical front, which is the condition for uniform distribution throughout the 30° angle. Two of these 16-horn nests were placed side by side to give the desired total of 60° horizontal coverage.

First Commercial RCA Two-Way Theater Speakers. In the RCA line of theater equipment a dual-range loudspeaker system was briefly described by J. Frank, Jr., at the 1935 fall meeting.[225] The speakers demonstrated by Dimmick and Belar, in 1932, using 6-in. cone diaphragms with aluminum voice coils, and 10-ft horns, were not seriously lacking in frequency range and were used in a number of deluxe installations, but they had two drawbacks. There were many theaters without sufficient room to install the long straight axis horns, and in addition, the high-frequency sound components were not well distributed. When a wave front reaches a point in an exponential horn at which the dimensions of the passageway are about a wavelength, its ultimate angle of spread will not greatly exceed the angle between the walls at that place. From this consideration it follows that a rapid flare horn would distribute the high-frequency sounds through considerably larger angles. Moreover with short rapid-flare horns, it is not impractical to multiply the number of units and thereby further control the sound distribution. In the theater speaker described by Frank, there were three high-frequency horns diverging in direction, the driver units being 6-in. cones with aluminum voice-coils.

These units were rated to operate effectively from 125 to 8,000 cycles, and a separate folded horn unit took care of sounds in the 40 to 125 cycle range.

One of the practical advantages of a direct-radiator (flat baffle) loudspeaker is the small space it requires. However a horn makes it possible to radiate more sound from a given-sized diaphragm without increasing the amplitude of motion, and is therefore desirable for increasing the sound output capacity. It also affords some control of the direction of radiation. But to radiate low frequencies the rate of expansion (ratio of increase in cross section per unit distance along axis) must be small, which for a given total ratio of expansion means length. One way to provide a long passageway without requiring excessive depth of space back of the screen is to coil up the horn. Drawings of coiled horns are shown in ref. 1, p. 298, and on p. 251 of the March 1937 *Journal*. The bending of large sound passageways is objectionable. Instead of expanding continuously as in the ideal horn, short waves suffer repeated reflections by the walls, causing some irregularities in the response and making the direction of radiation of high-frequency sounds rather unpredictable.* On the other hand if the horn is to handle only low-frequency sounds, the shapes of the bends are not at all critical, and the condition is easily fulfilled that the difference between the shortest and longest paths around a bend is a small fraction of a wavelength.

In a common form of low-frequency horn (in the sense of an approximately exponentially expanding passageway) the driver unit (or units) is at the middle of the back of a box-shaped space, and the passage is forward for a short distance, dividing and forming two passages which turn back and then forward and expand to form a pair of large adjacent rectangular openings, which together form the mouth of the horn. This roughly describes the low-frequency unit of the theater speaker system reported by Frank, the drivers in that case being a pair of 8-in. coil-driven cones.

Shearer System.[224] In 1936 Douglas Shearer, sound director for M-G-M, gave demonstrations of improved sound, using loudspeakers described by J. K. Hilliard in the July 1936 *Journal*. The high-frequency radiators in this system were similar in many respects to those used for the Auditory Perspective demonstrations (see figure in Hilliard paper). The frequency range to be covered was 50 to 8000 cycles, and the division or cross-over was at 250 cycles.

The low-frequency unit was a folded horn, with four 15-in. cones in a vertical column. For simplicity of construction the expansion was all in the horizontal

Fig. 16. Control of film speed by flexure (A. V. Bedford). Principle later utilized in nonslip printer.

plane, accomplished by suitably arranged vertical partitions. The horn cross section was divided into two expanding passageways, whose final openings together form a 68-in. square (Fig. 16). This was surrounded by a flat baffle 10 × 12 ft, to reduce end reflections and improve the loading of the units. The mean length of each passageway was 40 in. (very short as low-frequency horn designs go), nor was the expansion ratio large, the throat area being sufficient to accommodate the four 15-in. cones.

A nest of high-frequency horns, similar to that used for the Auditory Perspective demonstrations, three high by six horizontally, covered a horizontal angle of about 100°. With the lengths of the high- and low-frequency horns nearly the same, there would be little time difference in the arrival of the sounds at the plane of the mouths, thus simplifying the avoidance of a "phasing" error which has been found to have detrimental effects with transients. However, in all divided-range speaker systems the best relative positions of the high- and low-frequency units have been determined by careful trials. This problem of "phasing" is discussed by Maxfield and Flannagan,[225a] by Hilliard[226] and others. It appears to be not wholly a question of minimizing the mean time difference, although that is a part of it.

In all divided-range speaker systems, dividing networks[227] have been used to separate the high- and low-frequency portions of the amplifier output and direct each to the appropriate speaker units. The networks consist in general of simple filter sections, and their design has received much study.

Commercial Two-Way Systems. Commercial models of dual-range or "two-way" theater speakers were brought out in 1936, employing the multicell high-frequency horn system, and low-frequency units much like those described by Hilliard. The high-frequency driver units of the RCA system differed from the ERPI and Lansing designs in that the diaphragms were of molded phenolic instead of aluminum. This resulted in a more rugged, if less sensitive, device. The reduced sensitivity and greater "roll off," or falling off at high frequency, can be readily compensated electrically, and do not mean any serious increase in amplifier output power, because the high-frequency components of the sound represent only a small part of the total sound power.

The ERPI "Diphonic" speaker system is described in the Flannagan, Wolf and Jones paper.[222]

The description by Hilliard of the Shearer low-frequency unit may be taken as in general typical of the commercial speakers of 1936–7.

Divided channel or "two-way" speakers came into wide use during the several years following 1936.

In some later designs of low-frequency units, the sound passageway was not folded, and consisted only of a short flaring connection between the driver units (which presented a large total radiating surface) and the large opening in the flat baffle.* It is of interest that the evolution of low-frequency sound sources has been toward a closer resemblance to the cone and baffle speakers of 1925, but greatly magnified in size, and with some "directive baffle" effect better to control sound distribution.

Higher crossover frequencies than the 250-cycle point of the Shearer system have prevailed, 400 cycles being the choice in many of the postwar units. In 1948 Hopkins and Keith[228] described the design of a two-way theater speaker in which the crossover had been raised to 800 cycles, observations having been made that the irregularities which are apt to occur at the crossover frequency are less prejudicial if the crossover is above the frequency range of maximum energy (250 to 500 cycles for orchestra music).

A photograph of a loudspeaker designed to use with "Cinerama" is shown in the May 1954 SMPTE Progress Report, p. 343. This is more or less typical of recent practice. The horn (or directive baffle expansion passage) of the low-frequency units as well as that of the high-frequency unit is designed to give exponential expansion of the total cross section by side walls which are radial, the floor and ceiling of each passage being curved to compensate. The reflex, phase-inversion principle (mentioned under "Monitoring Speakers") is employed to utilize radiation from the backs of the diaphragms, for the extreme bass. Note in the illustration the outlet slots on either side of the horn mouth.

Alternatives to Multicellular Horns. A somewhat simpler way of achieving the directive characteristic for which the multicellular high-frequency horns were designed has been developed in the postwar period by RCA and others. Horns are used with linear expansion in the horizontal plane (i.e. walls radial with respect to the throat), while in the vertical plane the rate of expansion

* This effect can be largely reduced by careful design of re-entrant (zig-zag passage) horns.

* This would raise the "cutoff" frequency of the horn, but where the total expansion ratio is comparatively small that is not necessarily very significant. Below its "cutoff" frequency, an exponential horn does not impede sound transmission. It merely fails to multiply the volume displacement as it does above cutoff.

is such as to bring the total expansion of the cross section to an exponential relation.

Another expedient for gaining the desired spread of high-frequency sounds was described by Frayne and Locanthi at the May 1954 convention of this Society.[239] If the waves issuing from a straight-axis exponential horn can be made to assume a spherical instead of nearly flat front, they will spread as desired. An acoustic equivalent of a concave optical lens is placed in the mouth of the horn, in order to retard the off-axis parts of the waves relative to the central part. The reduced velocity of propagation is achieved by means of a series of closely-spaced perforated sheet-metal baffles, the number of layers being progressively greater toward the edges. This system was reported to have given smoother distribution than the multicell horns.

Monitoring Loudspeakers.[4,250,251] Wider-range monitoring speakers kept pace with theater speakers. While a single conical diaphragm can be designed so that the center portion radiates high frequencies and the outer area radiates low frequencies, best results have been obtained by using separate diaphragms and separate voice coils, or in other words resorting to the dual-range system. The upper- and lower-range units may be adjacent or concentric. In the latter case the low-frequency diaphragm becomes a directive baffle for the high-frequency radiator.

Permissible cabinet size tends to set the lower limit of the frequency range, air reaction on the back of the diaphragm creating the problem if the back is enclosed, or inadequate baffling if an open-back cabinet is used. In order to utilize the radiation from the back of the low-frequency diaphragm, a second opening is often provided (for example below the diaphragm) and the space in the cabinet used to provide a folded horn between the diaphragm and the opening, or else to serve as a simple chamber which acts in conjunction with the inertia reactance of the air at the second opening as a phase inverter. This does not greatly augment the low-frequency output except near the resonance, set by the elastic reactance of the cavity and the inertia reactance of the combination of openings (one with the diaphram and one without). Sound-absorbing material is often used in the cabinet to reduce the magnitude of other resonances. If the horn-type back-wave system is used, its augmentation of output is limited at the lower end when the phase shift through the horn becomes less than about a quarter cycle, and at the upper end by the fact that it is deliberately designed to have a low-pass filter characteristic.

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The third, and final, installment of this paper will be published in the August Journal.

Laboratory 16mm Striping Unit

By EDWARD SCHMIDT

Rapid increase in the use of 16mm magnetic-optical projectors, the advent of color television and its requirement for magnetic sound, and other commercial considerations led to the development of this striping unit. Its basic design features are listed briefly and its operation is described. The paper also contains information on the handling of the coating mixture used.

RECENT COMMERCIAL considerations have indicated the need for a laboratory 16mm striping unit. The widespread and rapidly growing acceptance and sale of 16mm magnetic-optical projectors have developed requirements for the striping of 16mm film that are beyond the ability of the present few striping stations to fill satisfactorily. The advent of color television and its requirement for magnetic sound, as well as the general availability of magnetically equipped 16mm projectors in television stations, are further persuasions for local striping facilities.

Accordingly the Model Z striping unit was designed to fill these needs. The basic design considerations are:

1. The unit must be completely self-contained and semiportable.
2. The speed of operation must permit commercial quantities of striping, at least 10,000 ft/8-hr day, including all make-ready and put-away time.
3. The unit must be equipped for constant operation but so designed that intermittent use is possible without long clean-up and preparatory time.
4. The unit must be operated by one man and simple enough to require only a short training period.
5. The unit must be capable of handling all three types of 16mm magnetic striping: double-perforated, 100-mil, and half-stripe single-perforated films according to SMPTE standards and recommendations.
6. The conversion from any type of stripe to any other must be quickly done (in less than a minute).
7. The basic design must include standard rollers, bearings, shafts, motors, etc., so that availability of replacement parts is simplified and production costs are minimized.
8. The quality of the finished striped prints must be above that of the most stringent commercial requirements.
9. The safety of design and operation must be considered, so that Underwriters' approval on the equipment may be expected, as well as that of any local inspection services.

Fortunately the complete acceptance of the Magna-Stripe design and principle by all CinemaScope producers has formed an excellent background for the design and construction of the striping head itself. The Model Z 16mm unit is a 2-stage 16mm version of the larger 4-stage, 35mm CinemaScope Magna-Striper. The same precision construction of film guides, rollers, striping applicators and adjustments is used on both equipments. Figure 1 illustrates a 35mm CinemaScope Magna-Stripe unit—complete with its oxide circulation system, etc. Figure 2 is a 16mm Model Z unit. Here we see that the oxide circulation system has been replaced with two one-pint plastic bottles holding the coating mixture.

Before the operation of the machine is described, it is important to consider the handling of the coating mixture itself. The useful life of the solution is at least three months from the date of shipment from the manufacturing plant. The mixture can be shipped by regular means in one-gallon cans like any enamel paint. No special storage is required. Preparation for use consists of vigorously shaking the cans for at least one minute before the mixture is poured into the plastic coating bottles. There is no demilling of this special dispersion during three months' shelf storage. There is a slight settling, leaving a thin liquid on top which is merely a portion of a thinner addition and does not indicate deterioration of the magnetic dispersion. This thin liquid immediately combines with the solution on slight agitation. Repeated tests have failed to show any increase in distortion or loss of high-frequency response of the mixture up to three months' undisturbed storage. These factors are the critical electrical indicators of the degree of dispersion of a magnetic mixture. This is a major stride over the condition of magnetic dispersions made two or three years ago when the useful life of the mixture, after milling, was measured in hours. The mixture is filtered through filters of the 2 to 4μ class as it is canned for shipment and no further filtering is required. Screens of 200-mesh 0.0021 stainless steel are inserted in the mouth of the plastic bottles prior to coating. These screens have a diagonal spacing less than one-fourth of the clearance of the orifice of the striping applicators and trap any hardened agglomerates of the coating mixture that may form around the mouth of the coating bottles during intermittent use.

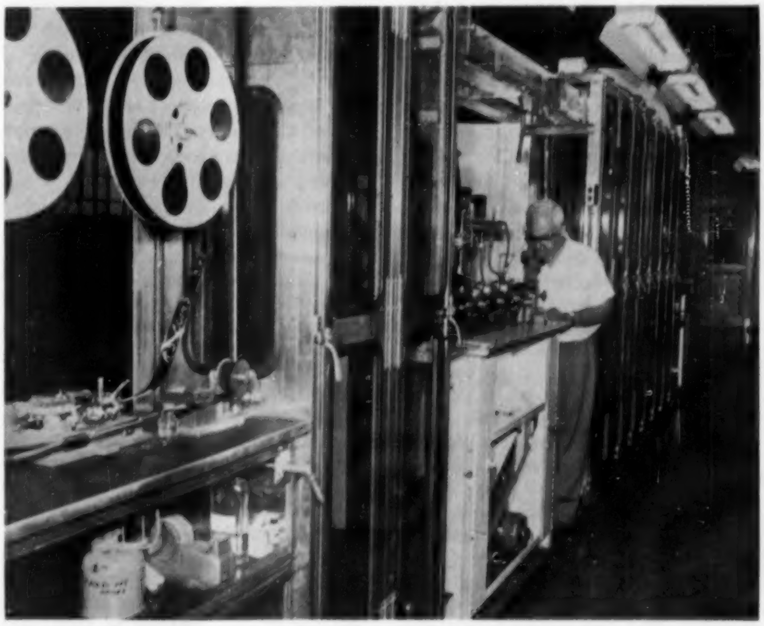

Fig. 1. 35mm CinemaScope Magna-Stripe unit with its oxide circulation system. DeLuxe West Coast Laboratories

Presented on October 20, 1954, at the Society's Convention at Los Angeles by Edward Schmidt, Reeves Soundcraft Corp., Magnetic Products Div., Springdale, Conn.
(This paper was received on January 18, 1955.)

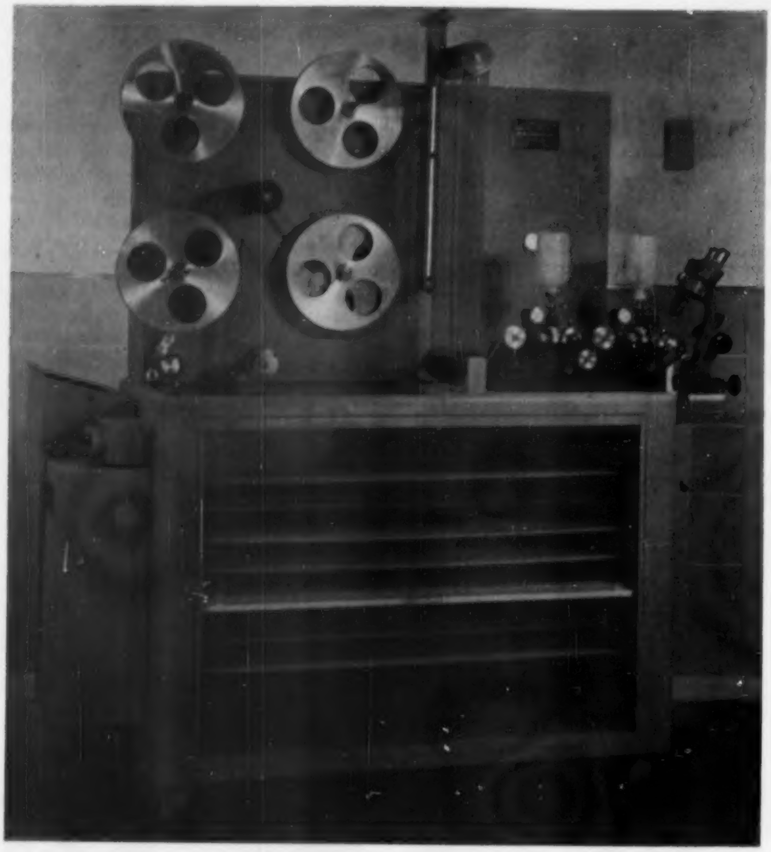

Fig. 2. 16mm Model Z unit.

The machine itself has two feed spindles which permit splicing of one reel to another, and a splicing elevator of 40-sec capacity, which is ample for quickly made, simple butt splices of pressure-sensitive tape. After the film passes over the two striping stations it goes through a pre-dryer section in the bottom of the cabinet where the low-boiling solvent components are evaporated at normal room temperatures and under relatively still air conditions. Then the film passes into the upper two sections of the drying chamber where elevated-temperature air completes the drying cycle. Two clutched take-up spindles are provided, and a basket on the lefthand side of the machine holds the loop of film as the operator changes from one take-up reel to another. A glass insert in the lefthand side of the top of the machine allows good observation of the film in the drying section and permits simple location of reel changes.

The air is drawn through the machine by the exhaust fan, which is coupled at the top rear of the machine to 6 ft of flexible ducting to permit dissipation of the solvent-carrying air to the atmosphere. Less than 125 g/hr are evaporated under constant operation of 100-mil striping. This design means that there is a slight negatine pressure in the drying compartment, so that there is minimal solvent odor in the operating room. The incoming air is passed over two finned-type Calrod heaters, which raise its temperature 20° at normal voltage. A thermometer is provided to check on the functioning of the heaters. The heater location is such that there is no possibility of the coating mixture ever contacting a hot element. The entire electrical system is of explosion-proof classification. An inching switch is provided, so that the cabinet can be rethreaded by one man without having the heaters in operation. The separating shelf and safety glass doors are readily removed from the cabinet to allow rethreading in case of a film break.

The roller shafts are all of a type that can be demounted quickly from the machine for washing and maintenance by the removal of one setscrew. The drive of the machine is of a friction type; no sprockets are used to pull the film. Good engineering practice is followed in the design of the drive to keep film tensions remarkably low. This is important because of the number of very poor splices one encounters in amateur film. In twenty days of operation of the prototype unit, one film splice parted. This was on a print that contained several hundred splices so poorly made that the inspector of incoming prints was certain that the film could not be processed. After this print was completed it would not run through our 16mm projector. One of every four or five splices came apart on projection. The film rollers are of the type that are relieved on the soundtrack side of the film to eliminate any possibility of scratches on the optical soundtracks or picture area.

The design of the striping heads may be interesting. Figure 3 illustrates the two striping positions. Here we see that the film is guided under the striping applicator by a fixed stud. The orifice of the applicator when mounted in position is adjacent to the vertical centerline of the precision roller. This threading path is extremely simple and provides the required accuracy of lateral guiding and flatness of the coated surface at the critical points. Extremely curled and warped prints run through the machine very well. The spacing of the guide shoulders on the fixed stud is less than the normal width of 16mm film, so that both edges of the film are effectively and accurately guided.

A jewelled-surface presser foot or shoe is pivoted under the orifice of the striping applicator in a manner that seals the edge of the stripe at a lap splice. This permits satisfactory striping of spliced prints regardless of the direction of the lap. The machine will operate very satisfactorily on unspliced new prints without having the presser shoe contact the film. Various width shoes are used for different width stripes and these shoes are readily placed on the pivot by swinging the arm down, away from the film. Lateral positioning of these shoes is obtained by means of an adjusting knob with a locking collar. The tension of the shoes in respect to the film is also readily adjustable to accommodate the occasional very badly warped print. Normally the tension is held very light to minimize any scratch problem that might be associated with dirty prints, but the very hard and smooth sapphire surface does not charge readily and scratches are not an operational problem.

The striping applicators are mounted in jeweller-lathe micrometer ways, which are connected to direct-reading dial micrometers. Thus the operator commands full control of stripe location as dictated by a reticule-equipped binocular microscope. The graduations in the microscope reticule are 0.002 in. and the stripe placement is readily positioned to this accuracy. The dial micrometers can be calibrated to read the distance from the edge of the film to the outside edge of the stripe, so that the centerline variation of 16mm variable-area tracks is readily accommodated far in advance

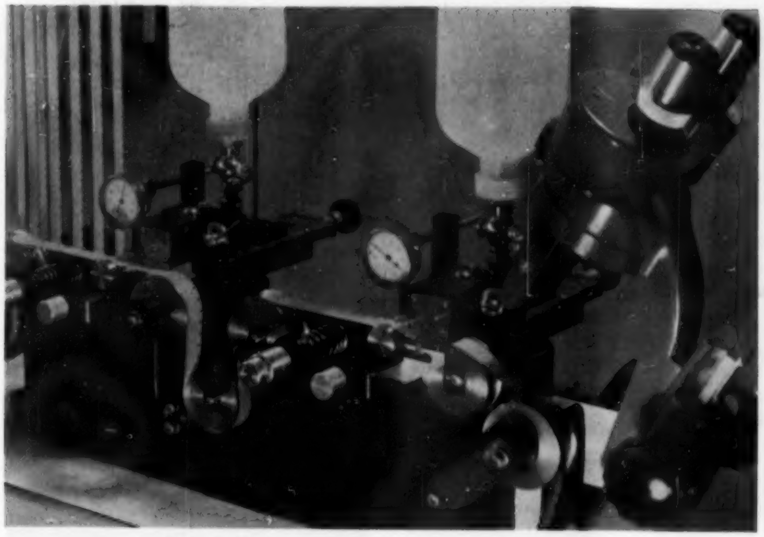

Fig. 3. Striping head showing two striping positions.

Fig. 4. Plastic bottles used in washing striping applicators.

of actual striping of one-half striped, photomagnetic tracks.

The striping applicators are instantly removable and can be interchanged by means of a cam lock which locates the applicator correctly on the head and seals the applicator port against a plastic bushing. The valve and piping assembly can be removed for washing by turning a single, coned lock screw. Under ordinary conditions, these assemblies are left overnight in a solvent wash tray so that there is no likelihood of oxide hardening.

The washing of the applicators is done by forcing solvent through them with the plastic bottles as illustrated in Fig. 4.

Nonmagnetic stainless-steel or chrome plated brass is used in all places in contact with the coating mixture. However, all prints should be bulk-erased after striping to minimize basic noise level.

The freshly coated stripes are quite hard and anchorage is good. However, immediate use is not recommended, as the hardening process continues for 48 hr, although a 24-hr period produces most of the chemical hardening change. The permanence of the striping on non-standard emulsion position prints is not guaranteed.

We have carefully tested all known commercial products coated on the emulsion side and in our judgment none of the processes produces a satisfactory bond. The variations in processing, chemical hardening, gelatins, and use conditions open to question any prints striped on the emulsion side. However, the permanence of the emulsion bond is greatly enhanced if the prints have been vacuum-treated prior to striping. The commercial vacuum-hardening processes compact and permanently shrink the gelatin of the film, in some cases by as much as 60%. This more compact and harder emulsion swells and shrinks less than untreated film during subsequent humidity excursions. Under these conditions satisfactory anchorage to the emulsion side is usually obtained. The permanence of the bond can be further enhanced if each print striped on the emulsion side is held at an elevated temperature of 110–120 F for 24 hr immediately after striping. Unfortunately, this practice is not commercially safe because of the instability of some types of safety base currently being used.

We have not had sufficient experience with the new Du Pont (Cronar) base to state whether the striping of this product can be done with the present formulation, but preliminary tests indicate that no problem will be encountered.

Recent Developments in Magnetic Striping by the Lamination Process

By RICHARD F. DUBBE

A new machine for the application of a magnetic stripe to 16mm and 8mm motion-picture film by a lamination process is discussed. The machine incorporates several new developments such as improved slitting, adjustable track position, a pre-size coater and a humidity cabinet with elevator. These improvements have made dependable striping on both the base and emulsion surface of the films possible and permit removal of the cellophane carrier in one operation.

THE BASIC lamination process consists of applying a special magnetic tape laminate to motion-picture film. The tape's backing is then removed, leaving an exceptionally smooth, flat magnetic track securely bonded to the film. A developmental machine for applying the laminate was described in a previous *Journal*.[1] This machine applied the ¼-in. laminating tape to 16mm or 8mm film with the tape overlapping the desired soundtrack area. The surplus tape was then slit from the film's edge and stored for later use. This system was quite simple, but it necessitated placing the track next to the film's edge.

Also, this developmental machine required an adhesive "setting" time of at least two hours before the plastic carrier could be removed and striping on certain color emulsions was undependable. A program was instigated to design and build a laminator with:

1. Adjustable track position;
2. Continuous plastic carrier removal in one operation;
3. Dependable striping on all types of film bases and emulsions.

This program resulted in the 3M Company Model 16CB Laminator shown in Fig. 1, which fulfills the above requirements.

Presented on April 21, 1955, at the Society's Convention at Chicago by Richard F. Dubbe, Minnesota Mining & Manufacturing Co., 900 Fauquier Ave., St. Paul 6, Minn.
(This paper was received on April 11, 1955.)

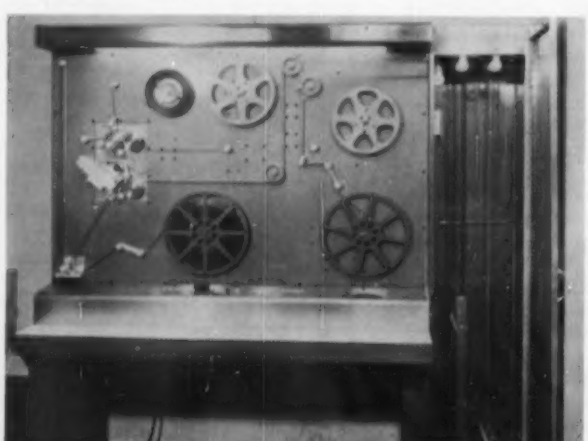

Fig. 1. Minnesota Mining & Mfg. Co. Model 16CB Laminator with humidity cabinet open.

The Laminating Machine

The laminating machine consists of four main parts: (A) the pre-coater, (B) the slitter, (C) the heater and pressure-roller assembly, and (D) the humidity cabinet and stripper. Two separate drive systems are employed. The main drive system pulls the motion-picture film through the pre-coater and pressure-roller assembly and feeds it into the humidity cabinet. The take-up drive pulls the film from the humidity cabinet past the stripper and winds it onto the take-up reel. An elevator, which is incorporated in the humidity cabinet, gives the operator an opportunity to stop the take-up and change reels without stopping the main drive. Thus, almost continuous operation is possible. The laminator operates at a film speed of 125 ft/min.

(*A*) *The Pre-Coater*. Before the film can be laminated, surface dirt, waxes and other foreign substances must be removed, and the surface prepared so that it will adhere to the laminating adhesive. This surface treatment is the function of the pre-coater. The pre-coater cleans and applies a microscopically thin coating of a pre-size solution to the soundtrack area. Since this coating is optically transparent, it does not affect the picture or photographic soundtrack, and the coating area does not have to be held to close tolerances. The pre-size solution is applied to the film by a wick through capillary action.

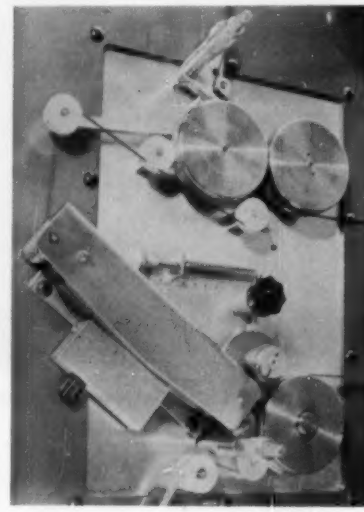

Fig. 2. Laminating mechanism. Shown are: (top) rotary slitting knives; (left) heater and thermostat; (lower center) tape guide and pressure roller.

(*B*) *The Slitter*. The laminating tape is supplied in 2400-ft lengths, ¼ in. in width. In order to slit the tape to the desired track width (100, 50 or 30 mils), the laminating tape is guided by a micrometer adjustment into a pair of rotary slitting knives (Fig. 2). The slit section then passes over a roller on a speed-control arm that regulates the rotational speed of the power-driven slitter knives. The knives actually feed the slit tape at a constant tension to the laminating mechanism. The unused tape section is wound onto a reel to be stored for future use. By pre-slitting the tape in this manner, the final magnetic track width can be controlled to within 0.001 in.

(*C*) *The Heater and Pressure-Roller Assembly*. The laminating tape has an acrylate-type adhesive that requires both heat and pressure to make it adhere properly to the motion-picture film. The function of the heater and laminating mechanism (Fig. 2) is, first, to heat the slit section of laminating tape to approximately 250 F, then to guide it accurately onto the motion-picture film where a pressure roller firmly bonds the magnetic oxide to the film. The tape guide has a micrometer adjustment cali-

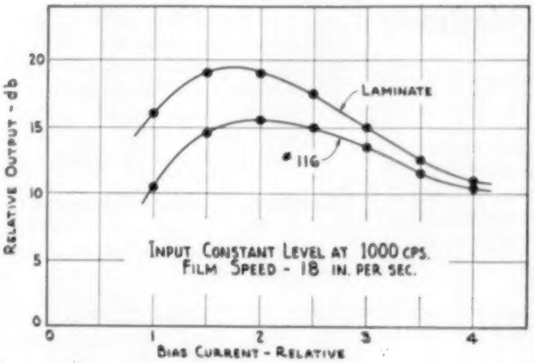

Fig. 3. Sensitivity vs. bias for 3M magnetic laminate as compared with No. 116 magnetic film.

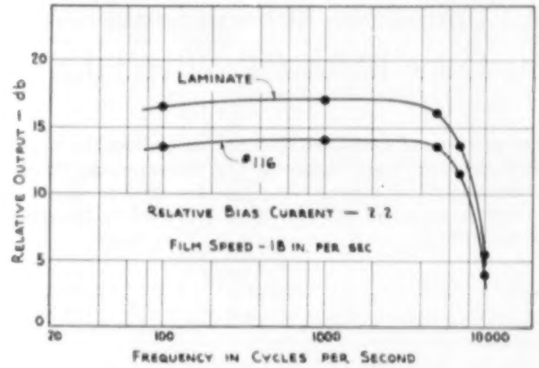

Fig. 4. Typical frequency-response characteristics for 3M magnetic laminate as compared with No. 116 magnetic film.

brated in distance from the film's edge. This guide serves two functions: (1) it compensates for variations in film width and (2) it permits placing a 50-mil magnetic track exactly over one-half of a photographic soundtrack.

(*D*) *The Humidity Cabinet and Stripper.* In order to soften the plastic tape backing and permit easy removal, the laminated film passes through a humidity cabinet and then to a stripping mechanism where the removable plastic backing is separated from the magnetic track and wound onto a take-up reel to be discarded. In normal operation, approximately 200 ft of film are in the cabinet. An elevator in the cabinet will hold an additional 50 ft of film, which gives the operator time to change take-up reels and to start stripping operations without stopping the main laminating drive system. A high percentage of relative humidity (85–90%) is maintained in the cabinet by the automatically controlled humidifier. An interesting effect of the humidity cabinet is often the improvement in the condition of badly distorted films.

Performance of the Laminated Track

Two older types of laminators have been in commercial operation for several years at the Calvin Co. and Capital Film Laboratories. In August 1954, the first of the new Model 16CB laminators was delivered to Capital Film Laboratories and in September 1954, a second unit was installed at the Color Reproductions Co. (The Calvin Co. and several other laboratories are scheduled to receive Model 16CB laminators soon.) To the present time, millions of feet of film have been successfully laminated on many types of 16mm and 8mm black-and-white and color films — on both base and emulsion surfaces.

The tracks laminated on these machines have several unique properties as compared with conventional liquid-coated stripes:

1. Their surface is flat and very smooth, ensuring good head contact, uniformity of output and excellent high-frequency response.

2. The laminating tape is precision coated on factory equipment and is held to the same close tolerances used on ¼-in. magnetic-recording tape (a uniformity of ±¼ db within a reel and ½ db from reel to reel. Thus, film laminated by different processors can be interspliced with excellent results).

3. The laminating tape oxide is oriented and is of 3M's "High Output" construction. This type of oxide gives from 5 to 14 db more output than conventional liquid-coated types (Table I).

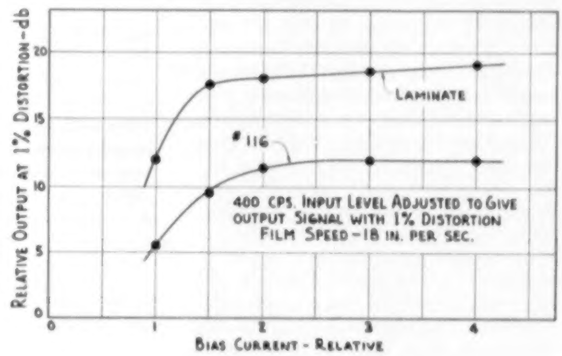

Fig. 5. Output at 1% harmonic distortion vs. bias for 3M magnetic laminate as compared with No. 116 magnetic film.

Table I. Relative Output of Several Types of 16mm Magnetic Stripes for 1% Harmonic Distortion, in db.*

Type of track	Track width in mils (approx.) 100	50	30
3M Laminate	64	57	47
Liquid Stripe "A"	53	45	33
Liquid Stripe "B"	59	52	40

* All tracks measured at "peak" bias, i.e., the bias that gives the maximum output of a low-frequency signal.

The recording characteristics of laminated track compared with 3M's full-coated "Scotch" Brand No. 116 are shown in Figs. 3, 4 and 5. For peak bias operation, the sensitivity of the laminate is 3.5 db greater, and its output for a given distortion is approximately 6 db greater than that of the No. 116. The frequency response is very nearly the same, with the laminate's output down about 1 db at 1.8-mil wavelength.

Acknowledgment

The author wishes to acknowledge the work of Jack Cahill, Minnesota Mining & Mfg. Engineering Dept., and Paul Ireland and his staff of the E.D.L. Co. in developing the laminating mechanism. The commercial success of the unit is largely due to the suggestions and field testing made by Arthur Rescher and Victor Patterson of the Capital Film Laboratories, Lloyd Thompson of the Calvin Co., and Reginald Dunn of the Color Reproductions Co. The writer wishes to express particular appreciation to Andrew H. Persoon of the Magnetic Products Laboratory, Minnesota Mining & Mfg. Co., for his guidance throughout the laminating program.

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A Comparison of Soundtrack Processing Methods for Color Release Positive Film

By JOHN L. FORREST

The problems of processing color release positive film to give a dye image and a silver soundtrack are discussed. The viscous image bleach method is described in some detail. The direct silver plus dye track produced by the viscous bleach method is compared with the track produced by the conventional redeveloped silver method.

THE MOST convenient way of producing a soundtrack is to use the material available, and it is little wonder, therefore, that in the early development of sound on film, silver was used for the light-absorbing medium. Its excellent light-absorption properties throughout the spectrum placed no limitations on the development of the light-sensitive surfaces.[1] Therefore the development followed the logical pattern of using substances with maximum radiant-energy sensitivity in a region where the radiant energy was most abundant. Hence the tungsten lamp and the cesium-silver oxide phototube with the silver soundtrack became the industry's standard for sound reproduction (Fig. 1). Had color film been available in those early years, it undoubtedly would have had a profound influence on these developments. It would have guided developments into channels more compatible with color-film requirements. The motion-picture industry was already well established, and practically every city in the country was already equipped with projection equipment to handle 35mm sound film before the problem of soundtracks on color film came on the scene.

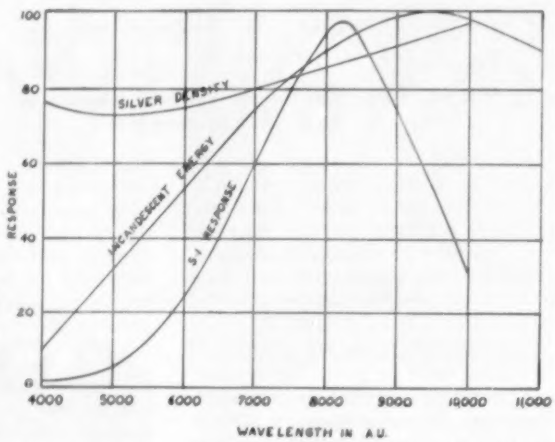

Fig. 1. Silver density compared with energy from an incandescent source and response of S-1 photosurface.

Developments in color film and particularly the multilayer film had to fit into the established pattern and perform satisfactorily on conventional equipment. As far as the picture is concerned, this presents no obstacle, but the sound is another matter. The dyes used in color processes have poor absorption in the infrared region of the spectrum (Fig. 2). Therefore, while being capable of producing adequate visual density, these dyes have very low density in the infrared region where the conventional phototube has maximum sensitivity and where the radiation from the tungsten lamps is most abundant.[2]

Several methods of overcoming these deficiencies have been proposed. In 1946, Glover and Moore[3] described the developments of a blue-sensitive phototube with its range of maximum sensitivity in the range of maximum absorption of the dyes.[4] This tube has now been brought to a stage of development where it is at least equal in performance to the conventional infrared sensitive tube used in most projectors, and it is now listed as standard in the catalogs (Fig. 3.) If this simple replacement of the infrared sensitive phototube with the blue-sensitive phototube[5,6] could be accomplished, it would simplify the processing of multilayer color film and would relieve the processing laboratories of the cumbersome steps of differential processing to

Presented on April 21, 1955, at the Society's Convention at Chicago by John L. Forrest, Motion Picture Development Laboratory, Ansco, Binghamton, N.Y.
(This paper was received on March 24, 1955.)

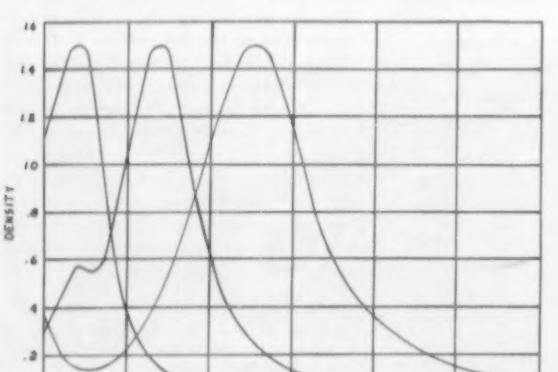

Fig. 2. Dye characteristics of Ansco color release positive film, Type 848.

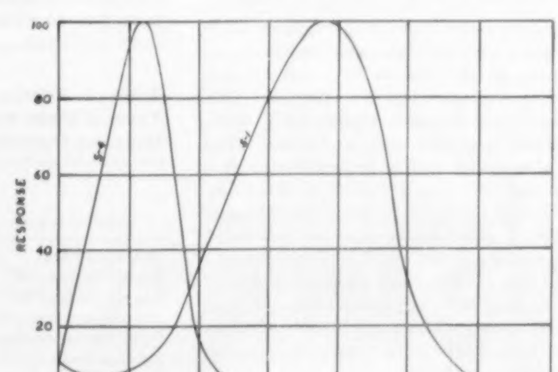

Fig. 3. Spectral response of S-1 and S-4 phototubes.

produce a silver track with a dye picture. This would save time, reduce cost and simplify the processing equipment design. Some consideration was given to this problem by the Color Committee of the SMPTE; however, no concrete recommendations have been made so far.[7]

A method of overcoming this difficulty in multilayer films involves differential processing to produce a silver soundtrack and a dye picture. This method is in rather general use.[1,8,9]

In this procedure, the soundtrack and picture are developed in the color-forming developer in the usual way. This gives a metallic silver and dye image. The film is fixed to clear the unexposed silver halides. It is then bleached to convert the original metallic silver image to silver salt. To give a metallic silver track, this silver salt is then redeveloped by local application of a developer in the soundtrack area only.[10] The silver salt in the picture area is removed after development of the soundtrack by immersing the whole film in a second fixing bath. Except for fixing, the soundtrack in multilayer positive-type film is completed in the first developer step simultaneously with development of the picture image. The problem in processing is to remove the silver from the picture dye image only and the undeveloped silver halide from the entire film. Fixing is the last step of the processing procedure and removes the unused silver halides from the entire film. The remaining problem is to remove the silver from the picture area without removing it from the soundtrack.

In this country the differential track redevelopment process has gained commercial acceptance. In Europe and England a direct approach to this problem was taken through bleaching of the picture area only, thus eliminating the step of reconverting the soundtrack and eliminating the need for the first fixer. This method of processing is known as the viscous bleach method and was first proposed by Agfa. In this procedure a bleach solution thickened to proper consistency to prevent spreading is applied to the picture area only.[11] Obviously, this must be done with precision equipment. However, application of the bleach solution to the picture area only is no more complicated than application of the soundtrack developer to the soundtrack area only. Both applications have to be accurately controlled in order to prevent overlapping of the picture into the soundtrack area or the soundtrack into the picture area. The working tolerances are similar for both processes. Commercial equipment is available for applying the viscous bleach to the picture area. André Debrie of Paris manufactures a precision viscous bleach applicator that is widely used abroad.

The viscous bleach method of processing multilayer color film results in a shorter process with fewer steps. Table I shows a comparison of silver track redevelopment and viscous bleach processing for release positive-type 848 Ansco Color Film.

Table I. Comparison of Two Methods of Processing Multilayer Color Film

Silver Track Redevelopment			Viscous Bleach Processing		
Step	Operation	Time required	Step	Operation	Time required
1.	CBC Removal	1 min 30 sec	1.	CBC removal	1 min 30 sec
2.	Developer	11 min (approx.)	2.	Developer	11 min (approx.)
3.	Rinse	20 sec	3.	Acid hardener rinse	2 min
4.	First fixer	4 min			
5.	Wash	4 min	4.	Wash	4 min
6.	Bleach	6 min	5.	Viscous bleach	6 min
7.	Wash	6 min	6.	Wash	6 min
8.	Soundtrack and edge rinse	30 sec			
9.	Final fixer	4 min	7.	Fixer	6 min
10.	Wash	6 min	8.	Wash	6 min
11.	Stabilizer	2 min	9.	Stabilizer	2 min
12.	Dry	30 min	10.	Dry	30 min

Since the bleach is restricted to the picture area, the first fixer is not needed to clear the unexposed silver halides from the track area. This can be accomplished by the final fixer simultaneously with the removal of the silver salts from the picture area. It also eliminates the need for the bleach tank. However, there is not much to be gained at this point because of the reaction time required after the viscous application. During the bleaching, the film can be run either in air or in an empty tank. The tank is preferable from the cleanliness standpoint. In machines designed for the application of this process, a suitable enclosure can be made. Clear plastic is generally used for this purpose as it permits convenient inspection of the bleaching step during the processing operation. The application of the thickened bleach solution to the picture area is much the same as applying the thickened soundtrack developer to the soundtrack area in the regular process.

There are a number of methods of applying the solution. The Debrie applicator shown in Fig. 4 works very well. In this equipment the thickened solution is extruded under low pressure on the moving film. The applicator is provided with a guide roller for the film, under which is mounted an applicator stage. The applicator consists of a plenum chamber with a fixed slot with two counterbalanced members located at each side of the slot to assist in guiding the application of the solution and restrict it to any desired position on the film surface. A shallow trough is built around this whole assembly in order to catch the overflow, which can be re-used. This entire assembly is built on a movable stage with micrometer vertical and horizontal adjustments. In addition to this, the whole assembly is fastened on a hinge arrangement with counterbalance. This permits the entire applicator unit to be moved out of the way when not in use. A built-in wiper is provided for cleaning the slot of the applicator. This is intended to free the slot of any lumps of the thickened bleach being fed to the unit. In our tests, however, we did not find that this was needed because the solution was well strained before being fed into the applicator. This is very important.

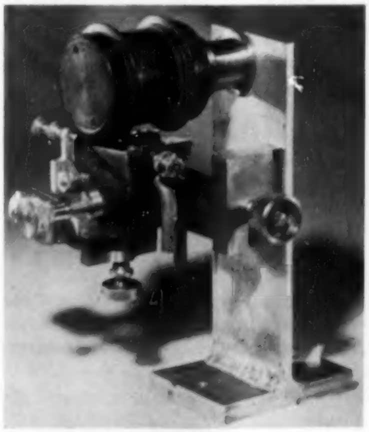

Fig. 4. Debrie applicator.

A formula found suitable for bleaching the film is a typical ferricyanide-bromide bleach formula such as the following:

Water: (70 F)	750 ml
Potassium ferricyanide:	100 g
Potassium bromide:	15 g
Add 8 g PVM/MA type 30, which has been wet with 80 ml. of alcohol	
Water to make	1 liter

It was found that the solution can be thickened with high viscosity, carboxy methyl cellulose, (CMC) or with PVM/-MA.* The physical properties of PVM/-MA are especially suitable for thickening the solution. This thickener has the ability to hold large quantities of an aqueous solution in a jelly form without setting. It does not make the removal of the viscous bleach difficult.

The bleach is fed under low pressure to the applicator. The ordinary working pressure is from 1 to 5 psi. Numerous pumps were investigated and tried.

* Half-amide of the copolymer of methyl vinyl ether and maleic anhydride manufactured by General Aniline & Film Corp.

Fig. 5. Pressure tank for supplying solution to applicator.

These included centrifugal, gear and the so-called nonpulsating pumps. Some of these pumps for all practical purposes are nonpulsating, but the requirements for a bleach applicator are so critical that the best pumps did not give sufficiently uniform flow. The problem of supply was finally overcome by using a pressure tank for supplying the viscous solution to the applicator with well-regulated compressed air (Fig. 5). Since the bleach is rather corrosive, the parts of the tank exposed to the solution were coated with rubber paint. This equipment was found satisfactory for experimental use and served the purpose of testing the process. For production use, a pressure kettle lined with an inert lining such as rubber would be more suitable. As an alternate method, the viscous solution could be flowed to the applicator by gravity if space was available. A vertical drop of about 10 ft would give the required pressure; however, considering the viscous nature of the solution, a very minimum of plumbing is desirable from the cleaning angle. The equipment should be capable of delivering the bleach within a range of from 1 to 5 psi. Under laboratory conditions about 2 psi was found best, using the Debrie applicator. This may have to be increased for higher machine speeds.

The problem of removing the viscous bleach from the film proved somewhat more difficult than the application. The viscosity of the solution was found to be quite critical. It must be thin enough to make a smooth application. The solution must have a surface tension low enough to avoid repellency and yield a straight edge. The solution must be thick enough for it not to run when in the vertical loops of the film during reaction. The thinnest possible solution meeting these requirements facilitates removal. A heavier solution can be applied, but removal will be difficult. Most of the solution was removed by a device with diagonal wipers. Experience in England and in European laboratories where the process has been used for a long time has indicated that the viscous solution acts as an excellent lubricant for the film, thereby preventing scratches in the removal process. The recovered solution can be adjusted in strength and re-used. Under proper operating conditions, very little will be lost. The remaining traces of bleach on the film are washed away in the wash following the removal. Since most of the bleach solution can be recovered, very little is lost, making this process very economical to use.

Sensitometrically, viscous bleach processing does not seem to make any practical difference on the final result. The comparative sensitometric results of the two processes are shown comparatively in Fig. 6.

(At the Convention, a film was shown comparing a film processed by the conventional silver track and redevelopment process used for Ansco Color release positive, type 848, and a section of the same film processed by the viscous bleach method.)

In conclusion, it was found that the viscous bleach method of processing multilayer color films is capable of producing results similar to the regular process in use in most laboratories at this time. The process makes it possible to convert small machines (lacking enough tanks) to color processing at minimum cost. The viscous bleach process is flexible, making it possible to change the developing machine from one process to another with minimum trouble when a change of bleach is required.

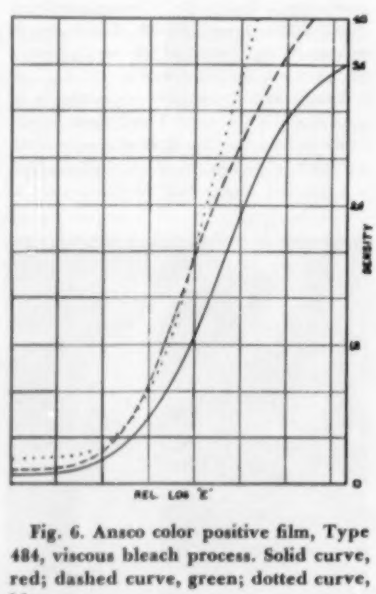

Fig. 6. Ansco color positive film, Type 484, viscous bleach process. Solid curve, red; dashed curve, green; dotted curve, blue.

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11. F.I.A.T. Report 721, Dept. of Commerce, Office of Publication Board, Report No. 15476, Jan. 1946.

Discussion

R. Paul Ireland (EDL Company): Is there any measurable difference between soundtracks produced by the viscous bleach method and the redeveloped silver procedure as far as high frequency is concerned?

Mr. Forrest: There is no decided difference in frequency response between soundtracks produced by the viscous bleach method of processing and the regular processing procedure. The redevelopment procedure, however, does produce some increase in output level of the track.

Mr. Ireland: You mentioned recovery of the viscous bleach. How is this accomplished?

Mr. Forrest: The used viscous bleach solution is removed from the film with soft rubber scrapers. It is then analyzed for ferrocyanide which is a measure of exhaustion. The ferrocyanide can be oxidized back to ferricyanide by any of the well known procedures. The difference in salt content between the rejuvenated bleach and the original formula is made up with fresh chemicals in relation to the original formula.

Mr. Jack Greenfield (Naval Photographic Center): Were the two samples printed from the same soundtrack?

Mr. Forrest: Yes, they were.

Mr. Greenfield: And was it a direct positive?

Mr. Forrest: No, it was printed from a negative soundtrack.

Mr. Greenfield: What was the approximate silver density of the viscous bleach sample?

Mr. Forrest: The maximum density of the soundtrack is about 2.0 effective infrared density.

Mr. Greenfield: I should have expected a greater signal-to-noise ratio in a track processed by this procedure.

Mr. Forrest: We did not find that there is anything to be gained in signal-to-noise ratio in films processed by this procedure as compared with the normal processing procedure.

A Report from the Association of Cinema Laboratories

By NEAL KEEHN

How and why The Association of Cinema Laboratories was formed, its proposed function and its relation to SMPTE are described. The work of committees already established to study business methods, standardization, nomenclature, etc., is reviewed. Committee activity has been guided by certain rules: (1) to determine what existing standards might be put to work by the individual member laboratories and (2) to consider what additional and/or expanded fields of activity would be better served by encouraging the establishment of further standards now nonexistent.

The Association was incorporated in March 1953 under the laws of New York State. Incidentally, we had planned to be The Association of *Motion Picture* Laboratories, but we found that this name had been used by a previous association, formed years before, that had never been legally dissolved. [A news story about the present Association's formation appeared in the July 1954 *Journal*, pp. 95–96.]

As of today we number 31 members. Twelve are in New York City: Color Service, Guffanti, Circle, Du Art, Movielab, Peerless, Quality, Titra, Mecca, Precision, Vacuumate and Video. Three are in the Washington area: Byron, Capital and National Cine in Hyattsville, Md. Four are in the Chicago area: Colburn, Atlas, Coronet and Lakeside in Gary, Ind. The other 12 are: Alexander of Colorado Springs, Calvin of Kansas City, Film Associates of Dayton, General of Detroit, Houston of Burbank, Iowa State College of Ames, Reid Ray of Minneapolis, Western Cine of Denver, and four Canadians — National Film Board of Ottawa, Northern Laboratories of Toronto, Shelly Films of Toronto and S. W. Caldwell Ltd. of Toronto.

The Association's start dates from the SMPTE Washington Convention of October 1952. Prior to that time, a number of us had become acquainted, at SMPTE meetings, or in competitive selling. Our conversations all pointed the same way: It would be mutually beneficial if we got together to discuss straightening out certain problems in handling film materials. Most 16mm laboratories had grown up separately and independently, and as a result there was considerable variety in the ways we prepared film for printing, in our method of handling, even in the words we used to do business. No wonder the producers were confused in dealing with us, when no two 16mm laboratories spoke the same language.

This was not a new problem. It wasn't even the first recognition of the old problem. As far back as the SMPE 1943 Spring Convention Lloyd Thompson of The Calvin Co. delivered a paper entitled "Some Suggested Standards for Direct 16mm Production" (published in the October 1943 *Journal*). And, incidentally, most of his suggestions are just now being developed and adopted. With these thoughts in mind, Mr. Thompson and the author sponsored an informal dinner at the Washington Statler, preceding the SMPTE meeting in October 1952. Six laboratories were represented, and the discussions begun that night, continued through the week, and were then adjourned to a meeting in New York in January 1953. Fifteen laboratories were represented at that meeting, and it was decided to form an association to be incorporated under the laws of New York State, because a majority of the laboratories were in New York. Provisional officers were elected, the Association was incorporated, and then the first board of directors was elected.

There are now nine Directors: D. M. Alexander Film Co., Robert F. Burns of Houston Color Film Laboratories, Kern Moyse of Peerless Film Processing Corp., Geo. W. Colburn of the Geo. W. Colburn Laboratory, Louis Feldman of Du Art, Saul Jeffee of Movielab, Neal Keehn of The Calvin Co., Charles Lager of Atlas and Byron Roudabush of Byron, Inc. Present officers include Mr. Roudabush as Secretary, Mr. Colburn as Treasurer, Russell Holslag of Precision as Vice-President and the author as President.

That is a brief summary of what has happened, what names are involved. The Association of Cinema Laboratories is now a two-year-old, and believes it has a man-sized job to do. We hope to become a nationwide working organization, in both 35mm and 16mm. The articles of incorporation laid out the job: "To cooperate in research and improvement of motion-picture laboratory procedures; to develop uniform product nomenclature; to publish information of general interest; to promote maintenance of high professional and ethical standards; and to promote good relations between members."

Now, that may sound pretty much like any other statement of purposes — possibly a little more down-to-earth — but it does raise two questions. What is the Association doing to live up to these fine-sounding phases, and what is the Association's position in relation to the SMPTE? Or, to put it another way, isn't the Association overlapping on established SMPTE functions? Well, let's answer the second question first.

The answer is No. There should be no conflict or confusion whatsoever. Rather, the Association can best promote its own aims by working with the SMPTE, through the established SMPTE committees, and under the SMPTE's general leadership. On specific points:

(1) The Association should and will adopt, publicize and utilize existing SMPTE-ASA standards that are applicable to the problems and needs of our members.

(2) The Association will work through established SMPTE committees to modify any existing standards which we feel do not fit the facts.

(3) The Association feels it can aid the Laboratory Practice Committee of the SMPTE by serving as a subcommittee. When we can reach agreement among ourselves on technical material, it will be sensible to submit our suggestions to the SMPTE Laboratory Practice Committee for further work and wider application.

(4) The Association will strengthen itself by promoting the aims and activities of the SMPTE. In connection with this point, I believe it would be fair to say that the Association has been directly responsible for bringing some laboratories into the SMPTE. A few years ago the 16mm laboratories in the SMPTE could be counted on one hand.

Now, I'd like to review briefly our present activities. Of course, we elect directors and officers, hold meetings in connection with the SMPTE semiannual conventions, and have an annual meeting in New York in January. However, our reason for existence is found in the work of our industry committees — three at present: Nomenclature, headed by Russell Holslag of Precision; Customer

Presented on April 19, 1955, at the Society's Convention in Chicago by Neal Keehn, (President of The Association of Cinema Laboratories, Inc.), The Calvin Co., 1105 Truman Rd., Kansas City 6, Mo.
(This paper was received on May 9, 1955.)

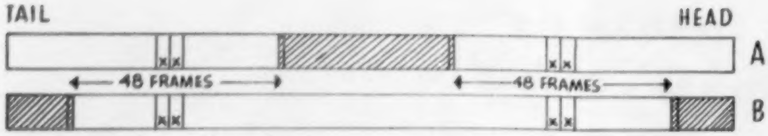

Fig. 1. A & B roll dissolves.

Relations, headed by Geo. W. Colburn of the Colburn laboratory; and Pre-Print Preparation, headed by Byron Roudabush, of Byron, Inc. In all of our work in developing standards we try to harmonize 35mm and 16mm standards. We will recommend separate 16mm standards only when we feel that 35mm practices are and should be different for good reason.

In working with nomenclature, Mr. Holslag has first gone over the existing SMPTE-ASA definitions, to make sure we don't duplicate work on a term already set. Beyond this, his efforts will go to pointing out to all Association members the existence of certain ASA standard definitions, and recommending that we cooperate fully in using the terms and the definitions. His committee is also working on terms commonly used, commonly confused and not yet defined. The Nomenclature Committee's present projects include definitions for words to describe different types of 16mm original camera materials and printing materials; definitions of various types of splices and splicers; and a clarification and unanimous decision regarding words describing the first print provided the producer for approval, the workprint materials used in editing and release prints. Some of these words and phrases are already defined in the ASA standards, others have not been defined. On all, we'll work for common agreement, common application.

In our second committee activity, we are directly concerned with ways and means of aiding the producer in laboratory relationship. George Colburn first questioned all members on certain business practices connected with Customer Relations. The answers were averaged out in tentative recommendations which were approved at our recent annual meeting, and they have now been submitted to the entire membership for final consideration and adoption. They include:

(1) No separate charge to be made for short ends in either black-and-white or color 16mm printing. (The cost of necessary footage waste to be covered by each laboratory's individual basic printing charge per foot or per section.)

(2) The laboratory to provide the printing stock, whether or not the customer prepays the stock cost. (The laboratory has primary responsibility to the customer for the characteristics of the dupe stock used, and represents the customer in any discussion with the film manufacturer.)

(3) The laboratory to carry legal liability insurance to cover normal business hazards, not specific title coverage. (There is no clear-cut insurance coverage of exposed or processed film in existing standard insurance contracts.)

(4) The laboratory to request confirmation in writing of all verbal orders. (As a means of reducing the possibilities of misunderstanding.)

(5) The development of a standard order form, as a model for member laboratories' own individual order forms.

Another recommendation defines pre-print materials length as sync-to-sync plus printing leaders. Other points now under discussion are the maximum number of splices allowable in the release print as made by the laboratory, a simple method for measuring and ordering replacement sections and further work on a standard order form.

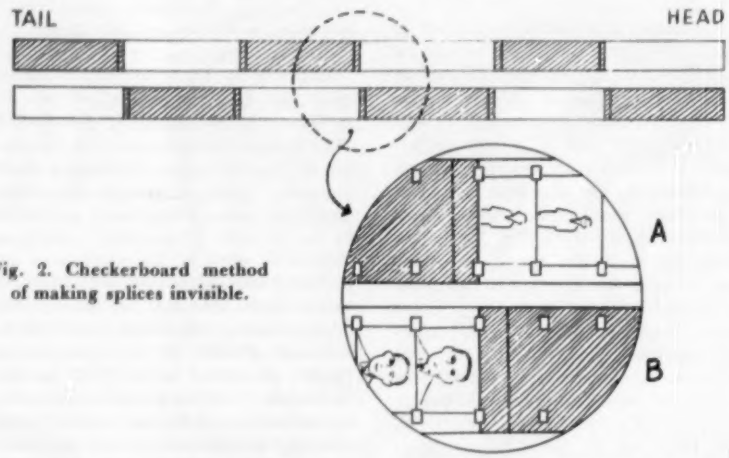

Fig. 2. Checkerboard method of making splices invisible.

The work of our third committee deals with the preparation of film materials. This work was begun under the chairmanship of John Stott, while he was a vice-president at Du Art. When Mr. Stott rejoined the Eastman organization in 1953, this project was taken over by Byron Roudabush, who now serves as chairman.

Tentative standard methods worked out and approved cover lengths and markings of leaders, and preparation of A & B rolls. On A & B rolls, we found variation in the length of the overlap requested by different laboratories, the type of film used in the connecting leaders and the method of splicing. The Association's tentative recommendations on A & B rolls are shown in Figs. 1–3. The recommendations include:

(1) An overlap of 48 frames. This will take care of the 40-, 44- and 48-frame dissolves and in-between variations. Although it does not cover the occasional

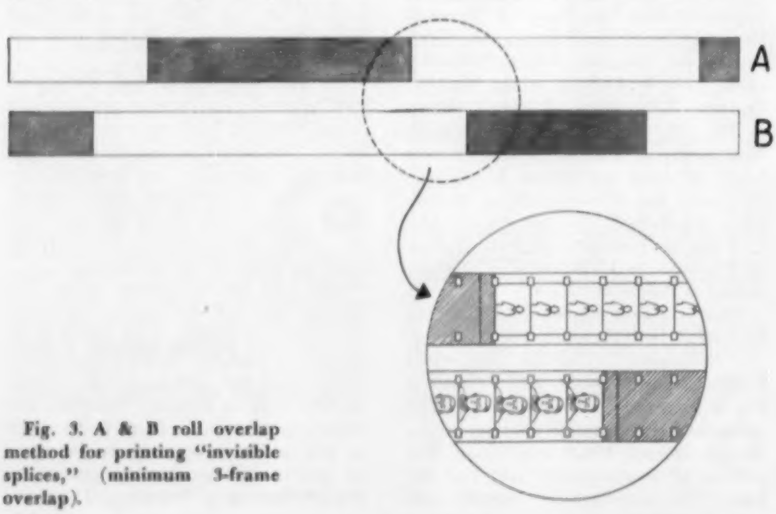

Fig. 3. A & B roll overlap method for printing "invisible splices," (minimum 3-frame overlap).

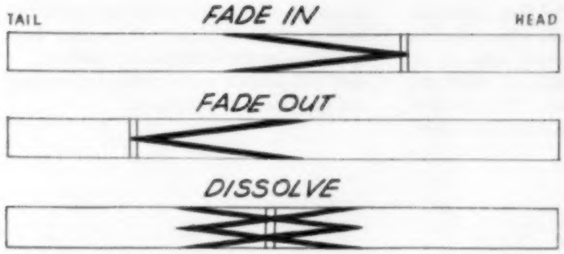

Fig. 4. Method of marking workprints to indicate effects.

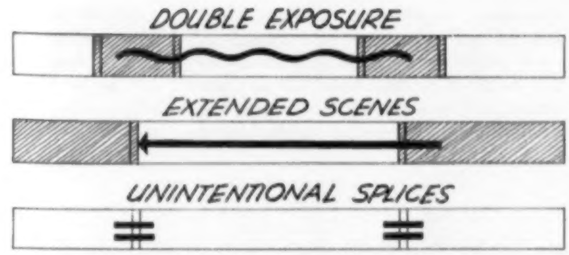

Fig. 5. Indicating double-exposure, extended scenes and unintentional splices.

requirement for a very long dissolve, the latter is usually a matter to be arranged between the producer and his laboratory, is not offered by all laboratories and is therefore not included in this recommendation. Although wipes are not specifically mentioned in the Association recommendation, the 48-frame overlap will cover them also.

(2) The use of black or opaque connecting leaders as a safeguard against undesirable light spill-over in the printing operation. We suggest the use of black leader made by full exposure of a positive stock, and development in a positive bath.

(3) Either of two methods for so-called "splice-free" straight cuts — the choice to be made by the producer in consultation with his laboratory. One is the checker-board method, as shown in Fig. 2 — the cut-across from A & B roll being made at the point where the straight cut is wanted, but the splice being made so as to place the splice-line in the leader material rather than the picture frame.

The other is the overlap method and it is based on the same A & B roll switchover, but the actual cutoff of printer light is done bv a traveling matte or an electronic control. In this method, an overlap of at least three frames is used. Preparation is as shown in Fig. 3.

(4) A method for marking optical effects and other instructions on the edited workprint, to provide information clear to any laboratory. These include, as shown in Fig. 4, a long "V" for a fade-in or fade-out. The point of the "V" indicates where the scene is to be totally dark. The direction of the point determines whether a fade-in or fade-out is desired. The same "V's" are used to indicate a dissolve, but are overlapped to show a dissolve rather than a fade-out, fade-in.

For double-exposure, superimposed titles, etc., a few inches of edge-numbered workprint of the scene to be double-exposed are to be cut into the edge-numbered workprint of the background scene — to indicate where the double-exposure begins and where it ends. Connecting the two short lengths with a wavy line indicates the full length of the double-exposure (Fig. 5).

Scenes to be extended are indicated by yellow leader the exact length of the extension, this leader being marked by a long arrow drawn through the splice connecting the workprint of the scene to be extended and the leader, the arrow's head indicating where the next scene begins.

Accidental or unintentional splices in the workprint are indicated by two short parallel lines drawn through the splice — so that the cutting mistake will not be repeated in matching the original.

The working out of a method of making and marking head and tail leaders proved to be a tough one. There was no hint of a common practice. Mr. Roudabush's suggestions for a tentative standard are based on compromises and incorporate the best of the various practices. They also incorporate existing ASA standard markings. The tentative standard is as shown in Figs. 6 and 7. The black leader separates picture — and track — from the white leader, at both head and tail. This will provide desirable opaque sections at both head and tail of the print, to aid in smooth projection presentation. The 2-ft black leader sections at the tail of the tail leaders simply provide fast identification of a tail-out winding. Other provisions are for complete identifying information on the printing rolls, print-through material to be transferred to the release prints, and — we hope — foolproof identification and separation of editing sync and printing sync marks.

When we have completed work on these various recommendations, to the satisfaction of the members of The Association of Cinema Laboratories, we will propose those concerning technical matters to the SMPTE Laboratory Practice Committee for further and careful consideration as industry-wide standards. And we will suggest to our members that they immediately use the accepted standardized methods in their own operations.

All of us who are members of the Association have heavy demands on our time — in connection both with the jobs we have in our own companies and with work in other industry organizations and activities. But we feel that time devoted

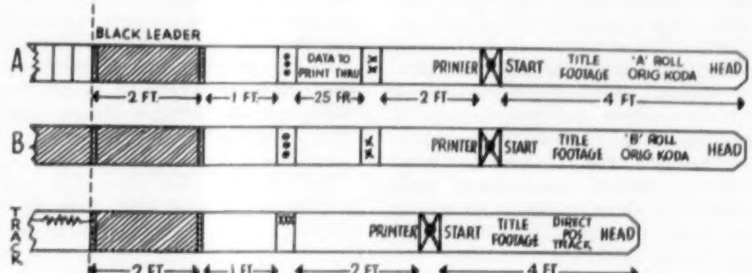

Fig. 6. Preparation of 16mm printing head leaders.

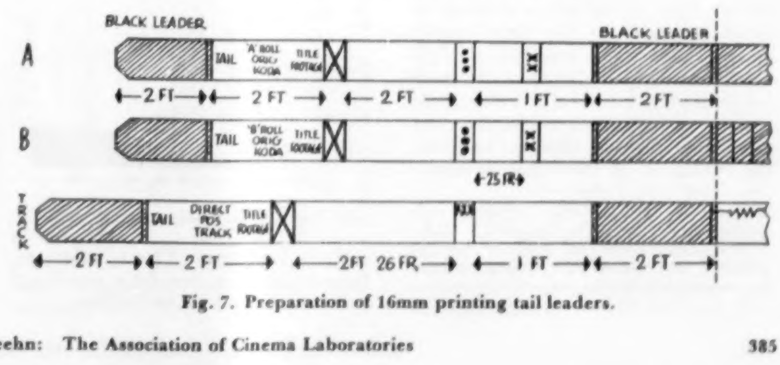

Fig. 7. Preparation of 16mm printing tail leaders.

to working together in the Association will be well spent if our efforts result in some aid to the SMPTE, in some clearing away of mutual suspicion or confusion, and — above all — in the active establishment of working methods and standards that will aid the film producer. The producer is the man who pays our bills by sending us his work, whether or not he is directly associated with the laboratory organization. We believe that an intelligent program of standardization and education will be of mutual benefit to the reputable laboratory firm as well as to the enlightened customer — and will provide a solid basis for a pleasant business relationship.

Preliminary Survey of Drive-In Theaters

By FREDERICK J. KOLB, JR.
Committee Chairman

In order to provide data on drive-in theater operation, the Screen Brightness Committee has sponsored a preliminary field survey. Measurements were made in 26 theaters among the eastern and central states, with screen widths about equally divided between the 40–60-ft and 60–120-ft range. Average screen brightness was 3.0 ft-L; no theater reached the indoor standard of 9–14 ft-L. Performance characteristics are summarized.

Previous studies of screen brightness in indoor theaters extending over a period of 15 years[2,3] have been instrumental in setting a theater screen-brightness standard, the latest affirmation of which has been published as PH22.39-1953.[1]

During the last 10 years the drive-in theater was developed and has grown so that this type of exhibition now accounts for about 23% of all the theaters in the U.S. and at least 20% of the box-office gross. The growth in number of drive-in theaters and their emergence as an important exhibition factor can be seen in Fig. 1.[4] From the very first, however, the drive-in theaters have been different in many important ways from the indoor theaters. It is of interest to the Screen Brightness Committee that they have operated consistently with lower screen brightnesses — partly for lack of practical means for putting enough light on the screen to cover at specified brightness the large screen areas dictated by the geometry of drive-in theater viewing. Inasmuch as there has been very little data on either trade practice or the requirements for good viewing in drive-in theaters, however, the evaluation of this trend in screen brightnesses has been difficult. Consequently, drive-in theaters were specifically excluded from PH22.39 when this standard was reaffirmed in 1953.

During the past year and a half the Screen Brightness Committee has been making measurements in a small group of drive-in theaters, in order to begin the accumulation of quantitative information. This study has been exploratory and preliminary since only 0.6% of the total U.S. drive-in theaters were measured. Even so, inspection of the data will show that there is already much that is useful.

Measured Characteristics

Considerable data about each of the 26 theaters were noted in order to have sufficient information to plan a more extensive survey if that should be desirable, to list the practical operating problems of drive-in theaters, and to assess the possibilities for changes in existing theaters. These observations may be grouped under the following general headings:

(1) Screen brightness including light distribution on the screen, variations between projectors, screen reflectivity, and directional performance.

(2) Geometric characteristics including theater size, screen size, aspect ratio and viewing angle.

(3) Equipment characteristics including light source and power supply, picture mechanisms and projection methods.

Some of the factors which now seem most significant are summarized in this report.

Methods and Instruments

Carrying on the policy of the most recent indoor theater survey, as many measurements as possible were made with

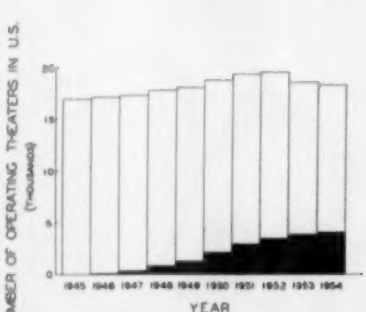

Fig. 1. Importance of drive-in theaters. Drive-ins now account for a significant percentage of exhibition facilities.[4]

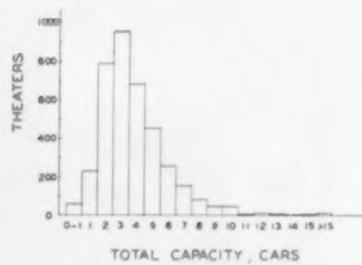

Fig. 2. Size distribution of drive-in theaters. Data from an industry survey of all U.S. drive-ins operating during 1954.[4]

Presented on April 22, 1955, at the Society's Convention at Chicago, by Frederick J. Kolb, Jr., Committee Chairman, Manufacturing Experiments Div., Kodak Park, Eastman Kodak Co., Rochester 4, N. Y.
(This report was submitted on May 19, 1955.)

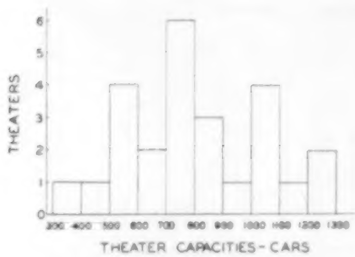

Fig. 3. Size distribution of drive-in theaters measured in the SMPTE Preliminary Survey.

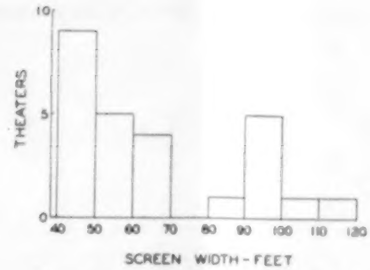

Fig. 4. Screen widths in the drive-in theaters measured in the SMPTE Preliminary Survey.

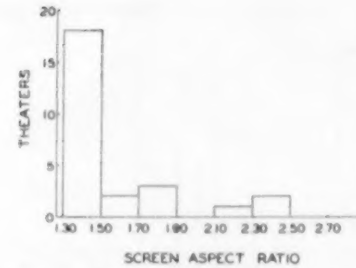

Fig. 5. Screen aspect ratios in the drive-in theaters surveyed.

objective-type instruments. Screen illumination was measured with the GE Screen Brightness Meter while most of the screen-brightness measurements were made with the Spectra Brightness Spot Meter. In a few of the theaters surveyed, brightnesses were also read with the Luckiesh-Taylor Brightness Meter.

Description of the Theater

Some of the information obtained may be used to evaluate the nature of our sample of 26 theaters and to judge how well this sample represents the more than 4000 drive-in theaters in the U.S. Figure 2 summarizes industry information on the distribution of all U.S. drive-in theaters according to theater capacity. Figure 3 gives this same information for the theaters covered in our preliminary survey.

Figure 4 tabulates screen widths in the theaters measured while Fig. 5 presents the aspect ratios of these screens. It will be seen that some very large screens were measured but that for the most part there were relatively few theaters, at the time of these measurements, converted to the high aspect ratio.

Certainly it would be desirable to see data on a great many more drive-in theaters, but the Committee believes the specifications for these 26 theaters show them sufficiently representative to define the general features of drive-in picture presentation.

Brightness Characteristics

Brightnesses measured at the centers of the screens in these drive-in theaters are summarized in Fig. 6. This curve has no similarity at all to the brightness distribution in indoor theaters as presented in Fig. 6 of the September 1951 report.[2] American Standard Ph22.39-1953[1] specifies a brightness between 9 and 14 ft-L *for indoor theaters;* actually 50% of the indoor theaters measured in 1950–51 fell within this standard, 26% were below the standard, and only one out of 125 indoor theaters was below 4 ft-L. In the drive-in group on the other hand (where PH22.39 does not apply) the average screen brightness is 3.0 ft-L and 82% are below 4 ft-L. In the drive-in group on the other hand (where PH22.39 does not apply) the average screen brightness is 3.0 ft–L and 82% are below 4 ft–L. There was no theater measured with a screen brightness in the 9–14-ft-L range.

Figure 7 presents the screen reflectivity in the various theaters indicating a wide range of screen surfaces from directional through matte and on down to inefficient surfaces that should be replaced. Figure 8 summarizes the total screen lumen output measured with the projector and its shutter running. These data indicate a range in projection equipment and in performance of this equipment all the way throughout the complete output range to be found in indoor theaters.

It is apparent therefore that the large screen size is not alone responsible for low screen brightness in drive-in theaters. There is a great deal of low-output equipment used in the smaller theaters, as if low screen brightness had been a design objective.

Brightness Distribution

Additional information about the appearance of these drive-in theater screens is contained in the measurements of distribution and of differences between projectors. Figure 9 presents the side-to-center distribution ratio and Fig. 10 the corner-to-center distribution ratio. These are almost identical with the similar curves in Figs. 7 and 8 of the September 1951 report[2] for indoor theaters except for the slight indication that the brightness in the corner of drive-in screens is frequently sacrificed in order to obtain higher brightness at the screen centers.

Figures 11 and 12 indicate the side unbalance and corner unbalance respectively for single projectors in these theaters. The curves are generally similar to those of Figs. 1 and 2 in the November 1951 report[3] on indoor theaters.

Differences between projectors in the same theater are shown in Figs. 13, 14 and 15 representing respectively the differences in center intensities, in side unbalance and in corner unbalance. These curves also are in general similar to Figs. 3, 4 and 5 of the November 1951 report.[3]

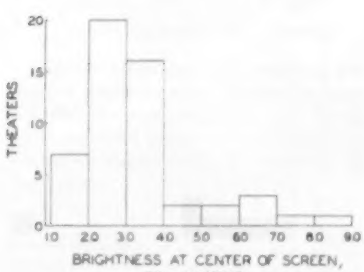

Fig. 6. Drive-in theater screen brightnesses. Data from 26 theaters measured 1953–54. The theater screen brightness standard does not apply to drive-ins.

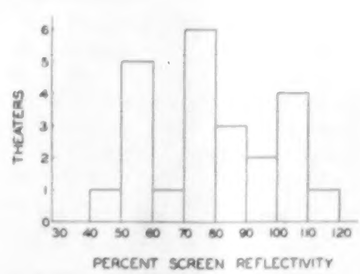

Fig. 7. Screen reflectivity in the drive-in theaters surveyed. Values above 100% indicate directional screens. Values below 60% or 70% imply deteriorated or dirty surfaces.

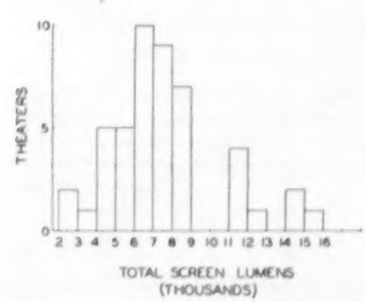

Fig. 8. Total screen lumens output from projectors in the drive-in theaters surveyed. Measured with projector and shutter running.

Uniformity of brightness over the screen surface, in the drive-in theaters surveyed

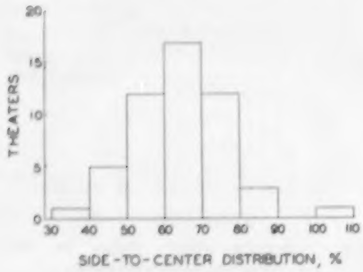

Fig. 9. Side-to-center distribution. Brightness at the sides of the screen as percent of center brightness.

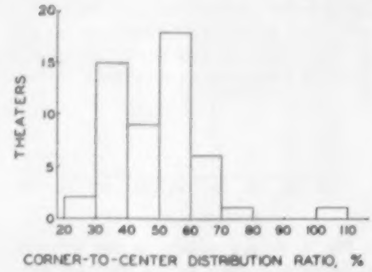

Fig. 10. Corner-to-center distribution. Brightness at the corners of the screen as percent of center brightness.

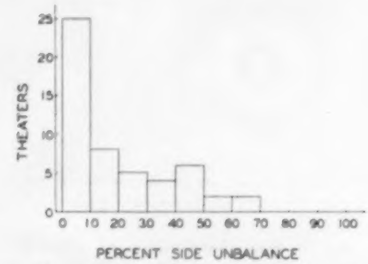

Fig. 11. Percent side unbalance. The difference in brightness between the right and left sides of the screen, as percent of the average side brightness.

It should be noted, however, that the measurement of brightness distribution in the drive-in theaters is a more difficult job because of the lower brightness levels and the fact that meters are, therefore, operated in less favorable portions of their scale. This means that the distribution measurements in this survey less accurately describe these drive-in theaters than the measurements in previous surveys describe the indoor theaters.

Other Theater Data

In studying these data from a preliminary survey of U.S. drive-in theaters there are many questions and uncertainties that cannot now be answered because we need more information about the nature of viewing under such conditions. It is one objective of this survey to point out more clearly what these viewing conditions are, and to encourage further work and study that will eventually define desirable standards for presenting the best practical picture quality in drive-in theaters.

Data on the optical problems of projection and viewing are of general interest and some of the figures are presented here. Other data are being studied by the Committee and will be available to all who are interested.

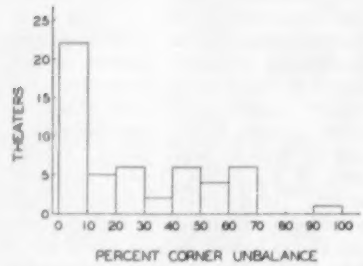

Fig. 12. Percent corner unbalance. The difference in brightness between the two corners measured, as percent of the average corner brightness.

Figure 16 describes the focal lengths of the projection lenses in the theaters measured. They are generally similar to those used in indoor theaters.

Specularity of the projection screen was inferred from the data of Fig. 7, where at least 20% of the theaters measured showed higher screen reflectivities than would be provided by matte screens. Further information is given in Fig. 17 where the screen brightness at approximately 18° off the axis is expressed as a percentage of the brightness when viewed along the axis. Values significantly below 100% identify screens which are specular, and which at the same time tend to show a brightness fall-off within the audience viewing area. More than 20% of the theater screens in Fig. 17 show such fall-off.

Much of the discussion of drive-in viewing centers on the apparent size of the screen from the audience position, or in other words the angle which the screen subtends at the observer's eye. Figure 18 presents an average condition — the horizontal angle subtended by the screen width when viewed from the center of the middle ramp. Approximate maximum and minimum values are shown in Fig. 19, where this subtended angle has been plotted for viewing from the center of the first and last ramps respectively. It will be noted that the actual screen widths used in drive-in theaters may carry a misleading impression, because they are viewed from such great distances as to "surround" the audience much less successfully than the smaller screens of indoor theaters.

Differences between the two projectors (especially visible at change-over) in the drive-in theaters surveyed.

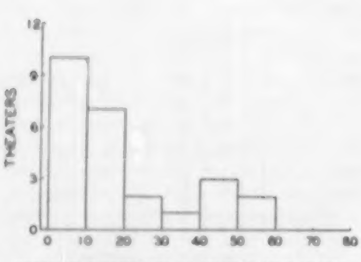

Fig. 13. Percent difference in center brightness. The difference in brightness between the two projectors, as percent of their average.

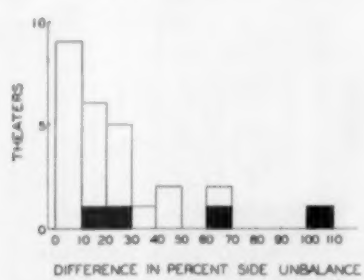

Fig. 14. Difference in percent side unbalance. The difference between the side unbalance measurements for the two projectors.

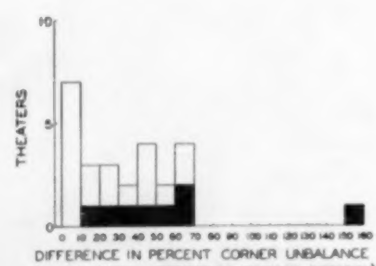

Fig. 15. Difference in percent corner unbalance. The difference between the corner unbalance measurements for the two projectors.

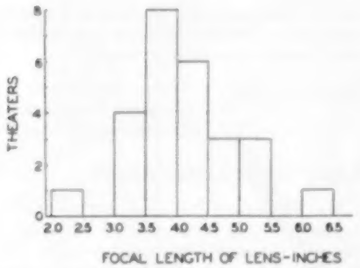

Fig. 16. Focal lengths of projection lenses in the drive-in theaters surveyed.

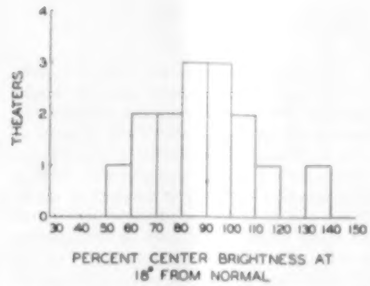

Fig. 17. Percent center brightness at approximately 18° from the normal. Screens showing a fall-off in brightness at an angle from the projection axis are unusually simple directional types; this fall-off means that patrons toward the side of the theater see a picture tht is less bright.

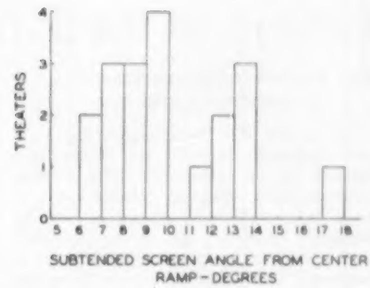

Fig. 18. Subtended screen angle from center ramp. If an observer at the middle of that ramp which is halfway back in the theater looks first at the left and then at the right edge of the screen, his eye movement measures the subtended angle. A large angle means that the screen seems big to the observer, a small angle means that the screen seems small.

Somewhat similar considerations enter into the selection of a screen size for a given theater. Figure 20 indicates the relationship between screen size and theater capacity in this survey, as feet of screen width per 100 cars capacity.

Discussion

These data are presented without evaluation because there are no generally accepted standards of performance for drive-in theaters. This preliminary survey has been intended not to rate the performance of existing drive-in theaters but rather to begin the consideration of factors important in setting desirable standards.

Data so far indicate that picture viewing in drive-in theaters is in many important respects different from viewing in the indoor theaters. Not only are the physical characteristics of the theater different but also the psychophysical audience viewing factors are completely different.

The Screen Brightness Committee is now studying these data to decide what further information is needed. This is presented as a progress report to encourage study and research needed to fill in the gaps in present knowledge. From data such as this and from careful studies of viewing the Committee hopes to present recommendations for the best quality drive-in viewing.

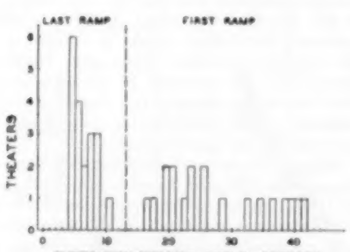

Fig. 19. Maximum and minimum subtended screen angles. Maximum angles for the theaters surveyed were measured from the center of the front ramp, minimum angles from the center of the back ramp.

Acknowledgments

The Screen Brightness Committee and the Society have had outstanding cooperation from a great many people in the conduct of this survey. Theater projectionists and their organization, the IATSE, and the theater managers have been most cooperative in permitting this survey and in assisting Committee members in obtaining the data. It has been most heartening to observe that all those directly associated with the presentation of drive-in motion pictures have been extremely anxious to help improve the quality of this form of entertainment. The Committee is particularly appreciative also of the assistance of C. E. Heppberger and others of the National Carbon Co. and of the assistance of many members of the Eastman Kodak Co. in carrying out the survey in different areas of the U.S. and in analyzing the information.

The Committee

Frederick J. Kolb, Chairman

H. J. Benham	G. Lessman
R. E. Birr	L. J. Patton
M. H. Chamberlin	Justin Paulauskas
B. S. Conviser	O. W. Richards
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A. J. Hatch, Jr.	G. H. Walter
L. B. Isaac	H. E. White
A. G. Jensen	D. L. Williams
W. F. Kelley	J. J. Zaro

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2. W. W. Lozier, Chairman, "Report on Screen Brightness Committee Theater Survey," *Jour. SMPTE, 57:* 238–246, Sept. 1951.
3. W. W. Lozier, Chairman, "Further Report on Screen Brightness Committee Theater Survey," *Jour. SMPTE, 57:* 489–493, Nov. 1951.
4. *Motion Picture and Television Almanac 1955,* Quigley Publications, New York.

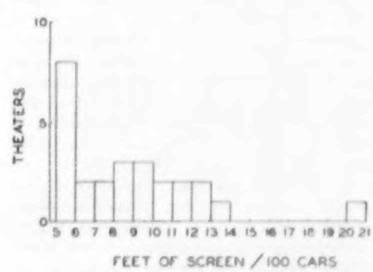


Fig. 20. Relationship of screen width to theater size. A summary in the theaters surveyed, of the design choice made in specifying a screen width appropriate to the theater size.

Letters to the Editor

Re: Exposure Measurement by Incident Light

The article "On Photographic Exposure and Exposure Meters" by Moon and Spencer in the December 1954 *Journal* contains much valuable information and leads to conclusions worthy of serious thought. However, its strong condemnation of the incident light measuring method ("The scheme is inherently wrong . . .") prompts one who has found the method useful to come to its defense.

As the authors point out, there is no single value for the "correct" exposure in any situation; therefore, no one metering method will always work perfectly when used by a robot. For various subjects the photographer should choose between various methods and should use his experience in interpreting the results. Let us consider an over-simplified type of situation in which the incident light metering method is the only inherently right procedure.

Suppose we are photographing a flat subject with a matte surface (for instance, a large water-color painting). Also suppose we are using a process which, without possibility of intermediate adjustment, gives a positive image and this image has a gamma of 1.0. Let's assume our photographer wants to make his picture look like the original — mainly light if the original is a light picture, or mainly dark if the original is a dark picture.

It is easy to see that metering this subject by the reflected light method would tend to shift the reproduction toward the middle of the tone scale of the process so that light subjects would be darkened and dark subjects would be lightened. This is true whether we use the method of measuring the lightest and darkest significant areas or whether we use an integrating type meter. In a transparency to be viewed alone in the dark the shift would cause no trouble, of course. But, if the final product is a print, this shift would make the picture look too light or too dark as compared with the original.

If the exposure is calculated from a measurement of the illuminance on the original, it is independent of the reflectance characteristics of this original. From knowledge of the process curve an exposure can be chosen which will make the final print match the original subject, density for density (except in the toe and shoulder), no matter whether the original is light or dark.

This metering method, like others, has its pitfalls in actual practice. Reversal processes don't all have 1.0 gamma and do have toes and shoulders. Solid objects do cast shadows on each other. The photographer still has to use his judgment and experience.

But the fact remains that many common photographic situations are nearly enough alike that described above so that the incident light metering method is a good, valid method for use in them and is often much better than other methods.

March 25, 1955 George Ehrenfried (Polaroid Corporation Cambridge 39, Mass.)

Reply to the Letter Above

Mr. Ehrenfried has suggested — quite rightly — that it is possible to obtain correct exposure by measurement of incident light instead of reflected light. Certainly there can be no quarrel with this conclusion. In fact, thousands of successful photographs are taken every day without benefit of any measurement or calculation.

But if we use measurement at all, why not measure the pertinent quantity? In all cases, the pertinent quantity is *the light reflected from the scene* toward the camera, not the light incident on the scene. This is true even for the highly artificial example considered by Mr. Ehrenfried. If he wishes to underexpose the dark picture and overexpose the light picture, he can obtain such effects equally well with the reflected-light method.

Any method of exposure calculation — or mere guessing — gives satisfactory results sometimes. But we claim that the incident-light method, since it measures a quantity that is only remotely related to the light on the film, is basically fallacious.

May 19, 1955 Parry Moon Domina Eberle Spencer

motion-picture standards

Revision of Two American Standards

Proposed revisions of American Standards Z22.9-1946, Emulsion Position in Camera for 16mm Silent Motion Picture Film, and Z22.10-1947, Emulsion Position in Projector for Direct Front Projection of 16mm Silent Motion Picture Film, are published here for a three-month period of trial and criticism. All comments should be sent to Henry Kogel, SMPTE Staff Engineer, prior to October 15, 1955. If no adverse comments are received, these proposals will then be submitted to American Standards Association's Sectional Committee PH22, for further processing as American Standards.

The subject matter of these standards was first proposed for standardization around 1932 and then only for 16mm film with perforations along one edge, 16mm sound film. This became an SMPE standard in 1934. In 1941, standards for both 16mm film with perforations along one edge and along both edges were approved by both the Society and ASA. About that time, technical advances in the methods of processing 16mm film made it commercially advantageous, in certain applications, to process 16mm prints so that when projected, the emulsion side of the film was in the nonstandard position or facing the light source rather than the lens. A more detailed explanation of this situation may be had by reference to a paper by W. H. Offenhauser published in the August 1942 *Journal* and to a report by J. A. Maurer published in the December 1947 *Journal*. The Maurer report was the basis for the action taken in 1946–1947 by Sectional Committee Z22 (reconstituted in 1950 as PH22) to reaffirm these standards with only minor editorial modifications.

A few years later, the widespread use of 16mm sound film as source material for television and the fact that this film was not supplied uniformly with the emulsion in the standard position forced the Society to take a new look at this question. On the surface, the nonuniformity of end product in an area where a standard was supposed to prevail appeared so anomalous as to occasion the 16 & 8mm Committee to take steps to completely withdraw Z22.10-1947 for silent film and Z22.16–1947 for sound film.

However, before this action was concluded, the Society conducted an open forum on this question during the 70th Convention in Hollywood on October 17, 1951. Data supplied at this forum indicated that the situation was not as bad as it had appeared. Well over 80% of the film then used in television was supplied with the emulsion in the standard position and the general consensus was that the solution lay in the direction of continuing the existing standard with efforts made to encourage all concerned to order and supply 16mm prints with the emulsion in the standard position. A few mimeograph copies of the verbatim report of this forum are available and may be had upon request.

Based on those conclusions the 16 & 8mm Committee reversed its previous position and took steps to reaffirm the two standards. This process was delayed by the introduction of a new question: that the projection rate for silent film be increased to 18 frames per second while maintaining the camera rate at 16 frames per second. The argument for the increased projection rate was predicated on the need to solve the flicker problem which was becoming more and more objectionable as the brightness level advanced. This argument finally prevailed and the draft standards were unanimously approved by both the 16 & 8mm Committee and the Standards Committee. It should be noted that these standards differ from the 1946 and 1947 versions by the addition of an explanatory appendix, a change in title and in the case of PH22.10, an increase in the rate of projection from 16 to 18 frames per second. — *H.K.*

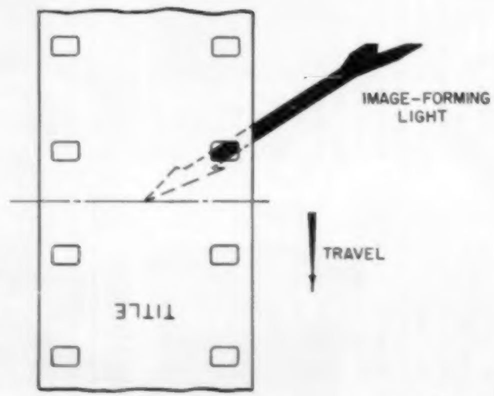
Proposed American Standard

16mm Film Perforated Along Two Edges, Usage in Camera

(Second Draft)

PH22.9

Rev. Z22.9-1946



Drawing shows film as seen from inside the camera looking toward the camera lens.

1. Position of the Emulsion

1.1 Except for special processes, the emulsion shall be toward the camera lens.

2. Rate of Exposure

2.1 The normal rate of exposure shall be 16 frames per second.

APPENDIX

Section 2.1 giving the normal rate of exposure as 16 frames per second is in apparent contradiction with Section 2.1 of PH22.10 which specifies a normal projection rate of 18 frames per second. In modern 16mm practice, however, 16mm film perforated along two edges is used primarily in the amateur field; cameras designed for the amateur are usually spring wound, portable, and not closely governed in taking speed. Variations from 18-14 frames per second at least are commonly observed. It is not customary to design amateur projectors which will reproduce exactly the taking speed and as a matter of fact it has been found that for amateur cinematography this exact speed reproduction is not necessary. Projection at 18 frames does not detract objectionably from films exposed at 16 frames or even at 14 frames and it has the advantages discussed in PH22.10.

Therefore, the camera speed of 16 frames per second is regarded as an aim to which considerable tolerances will normally apply. Pictures taken in cameras having this speed tolerance, as well as pictures taken in cameras having constant-speed motors governed at 16 frames per second, will show some change in the velocity of movements when projected at 18 frames per second, but this is not considered objectionable.

NOT APPROVED

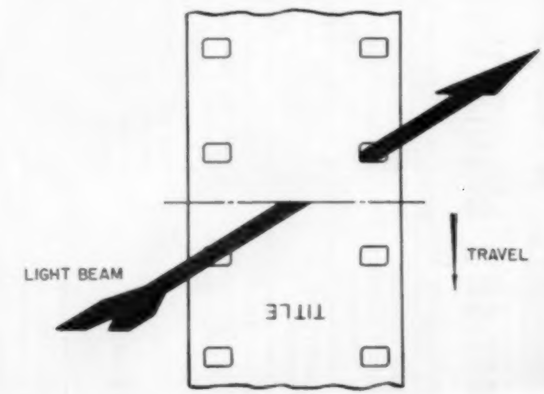
Proposed American Standard

16mm Film Perforated Along Two Edges, Usage in Projector

(Second Draft)

PT22.10

Rev. Z22.10-1947



Drawing shows film as seen from the light-source in the projector.

1. Position of the Emulsion

1.1 Except for special processes, the emulsion shall be toward the projection lens. This applies to direct projection on a reflecting screen. If a translucent screen is used, or if the image is reversed left for right by other optical features, the film can be turned around so that the emulsion is toward the projection lamp.

2. Rate of Projection

2.1 The rate of projection shall be 18 frames per second.

NOTE: In projectors having a fixed rate of projection, the projection rate shall be 18 frames per second with a tolerance appropriate for the use to which the projection at this rate is to be put. Projectors having manually adjustable speed shall be capable of reaching a projection rate of at least 18 frames per second.

APPENDIX

In modern 16mm projection practice the use of film perforated along two edges is primarily confined to the amateur field. This equipment is usually portable, the available screen sizes are frequently limited with many common screens small in size and of high gain, and many of the projectors have a high light output. Under these conditions it has been observed that frequently very high screen brightnesses are obtained and that the audience is usually aware of flicker before they are aware of changes in the pictorial quality of the projected pictures. It has been industry practice, therefore, to extend the flicker threshold by choosing as high a projection rate (and, therefore, as high a flicker frequency) as is practicable. A projection rate of 18 frames per second and a corresponding flicker frequency of 54 cycles per second (obtained with a 3-blade shutter) has been found by experience to be an acceptable compromise.

NOT APPROVED

news and reports

The Papers Program for the Fall Convention

The structure of the program of papers for the 78th SMPTE Convention, October 3–7, at the Lake Placid Club is being completed rapidly. Plans are well under way for four round-table discussions by leaders in the industry.

One of the highlights of the meeting will be the round table on Thursday morning, October 6, on "*Problems of Network Broadcasting in Monochrome and Color*," moderated by T. Gentry Veal, Chairman of the SMPTE Television Committee. This discussion will feature distinguished engineers from each of the major networks, including William Lodge, CBS; Robert Shelby, NBC; Frank L. Marx, ABC. The round table will also include talks by Frank Cowan, Long Lines Dept., A. T. & T., New York; and Phil B. Laeser, Station WTMJ-TV, Milwaukee.

In addition to this round table, several excellent papers on television practice have been scheduled, including:

"Grainless Phosphor Screens for Television Tubes and the Light Amplifier," Dr. Frank J. Studer, Research Laboratories, General Electric Co., Schenectady, N.Y.

"New Du Mont Vitascan," J. L. Caddigan, J. H. Haines and T. T. Goldsmith, Jr., of the Allen B. Du Mont Laboratories, Passaic, N. J.

Besides this important session on Television Practice, the Papers Committee is working on five other sessions under chairman supervision as follows:

1. *New Color Films, Their Properties and Uses* — G. E. Matthews, Research Laboratories, Eastman Kodak Co., Rochester, N.Y.
2. *Studio Production Problems* — Petro Vlahos (replacing Arthur Blaney who had to resign in favor of other duties), Motion Picture Picture Research Council, 1421 North Western Ave., Hollywood 27.
3. *Laboratory Practice* — Gordon A. Chambers, Motion Picture Film Dept., Eastman Kodak Co., 343 State St., Rochester 4, N.Y.
4. *Projection and Viewing* — Dr. Charles R. Daily, Paramount Pictures Corp., 5451 Marathon St., Hollywood 38.
5. *High-Speed Photography Symposium* — John H. Waddell, Fairchild Camera and Instr. Corp., 88-06 Van Wyck Expressway, Jamaica 1, N.Y.

Work is also under way to hold a special session on Friday, October 7, devoted to the rapidly growing subject of Educational Television. Representatives of leading organizations in this field have been invited to present papers covering their work. It is felt that the members of the Society can benefit greatly from an informative discussion on the subject of applications and future plans for Educational Television.

Your Papers Committee will continue to work hard to make this Meeting one of the most interesting and informative occasions in the history of our Society. Plan now to attend and enjoy the beautiful scenery at Lake Placid in October and renew friendships as well as make new friends at the 78th Meeting.—*Glenn E. Matthews*, Papers Program Chairman, 78th Semiannual Convention.

TV Color Test Films and Slides

Thirty-five millimeter and 16mm color television test films and 2 × 2 in. slides are now available from the Society. These were produced under specifications established by the SMPTE Television Committee under the chairmanship of Gentry Veal.

Committee members G. C. Misener of Ansco, S. E. Howse of Technicolor and T. G. Veal of Eastman have very generously made available specially prepared color negatives at no cost to the Society from which supervised prints have been made. Each print represents the quality of color material obtainable from these three companies. There are five scenes on each material. At the beginning of the first scene a gray scale is included which can be used in set up or for adjusting the signal-generating equipment so that the chrominance subcarrier vanishes.

The 2 × 2 in. color slides made by Ansco and Eastman contain the same high-quality picture material used in the test films.

The scenes include a variety of settings, both interiors and exteriors, and a wide range of colors.

All scenes in both slides and films were illuminated for shooting with a lighting ratio of approximately 2:1, that is, the key light was twice the fill light as measured in foot-candles.—*Fred Whitney*, Test-Film Engineer.

International Standardization Meeting

The meeting of Technical Committee 36 on cinematography, sponsored by the International Organization for Standardization in Stockholm, June 11–16, resulted in decisions on 14 proposals to help further international exchange of film products. This general, preliminary account of the meeting will be followed by a detailed report in a future issue of the *Journal*.

The meeting was attended by more than 40 delegates from Belgium, Czechoslovakia, France, Germany, Italy, the Netherlands, Russia, Sweden, the United Kingdom and the United States. The delegates adopted a proposal made by the United States delegation for the cutting and perforating of 35mm film for use in CinemaScope.

Agreement was also reached on the definition and methods of testing safety film; and although no final agreement was reached on marking of safety film, the delegates did take some initial steps toward establishing an international standard in this area. Among the existing national systems of marking safety film that were examined were the laws of the French and German governments and the voluntary standard followed by the English.

Seven permanent working groups were appointed to cover questions of wide-screen picture standards, film dimensions, screen luminance, reproduction characteristics of magnetic sound, film image area, safety film definition and marking, and location and dimensions of magnetic tracks. These groups will remain in existence until the next international cinematography meetings are held.

The committee on location and dimensions of magnetic tracks was authorized to draft a proposed ISO standard for one present optical and two new magnetic tracks on a single standard 35mm release print. Such a proposal, if adopted, would simplify the distribution of foreign film.

The term "screen luminance" was adopted by the group as the official one for use in the future, in preference to "screen brightness."

Among other U.S. proposals adopted by the delegates were cutting and perforating dimensions for 35mm motion-picture negative raw stock, dimensions for 35mm motion picture short-pitch negative film, dimensions for 100-mil magnetic coating single-perforated 16mm motion-picture film, and magnetic coating — 16mm magnetic-photographic sound record.

Axel G. Jensen of Bell Telephone Laboratories, Inc., Engineering Vice-President of the Society, was Chairman of the cinematography meetings. Boyce Nemec, SMPTE Executive Secretary, was Secretary.

The United States delegation was headed by Dr. Deane R. White of E. I. du Pont de Nemours & Co. Other members of the U.S. delegation included William F. Kelley of the Motion Picture Research Council, J. W. McNair of ASA, Marion E. Russell of Eastman Kodak Co., Allen Stimson of General Electric Co. and Malcolm G. Townsley of Bell & Howell Co.

Among the delegates from other nations were the following SMPTE members: Jean Vivié and Louis J. J. Didiée, France; Dr. Hans-Christoph Wohlrab, Germany; Libero Innamorati, Italy; Stellan Dahlstedt, Harry Enequist and Holger Marcus, Sweden; and Doctors Leslie Knopp and Otto K. Kolb, the United Kingdom.—*S.G.*

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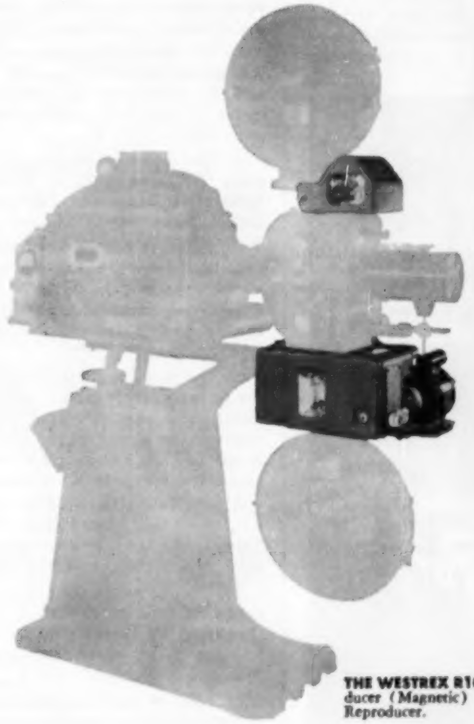

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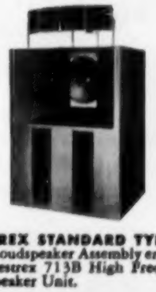

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FORMERLY WESTERN ELECTRIC EXPORT CORPORATION

Education, Industry News

Historical Exhibit, 1955 Wescon — is to be a feature of this year's Western Electronic Show and Convention, to be held in the Civic Auditorium in San Francisco, August 24–26. The Wescon release describes items to be on display as:

1. The basic unit of all electronics, the three element vacuum tube, the triode, developed by Dr. Lee de Forest.

2. Pictures and literature on the Poulsen Arc C. W. Generator, invented by Dr. V. Poulsen in Denmark.

C. F. Elwell, a Stanford graduate in electrical engineer, after a year of experimentation between Palo Alto and Los Altos with radio telephony and means of generating h-f continuous waves suitable for radio work, went to Copenhagen and obtained an option to purchase the U.S. patent rights to the Poulsen Arc.

Encouraged and assisted by Dr. David Starr Jordan, President of Stanford University, and Professor Haris J. Ryan, head of the electrical engineering department, Elwell founded the Poulsen Wireless Telephone and Telegraph Company, later to be known as the Federal Telegraph Company.

In February 1910, demonstrations of radio telephony and telegraphy were made between the first two C. W. radio stations at Stockton and Sacramento, Calif., 50 miles apart. Within two years, 16 commercial radio telegraph stations were added to these two, forming a chain from Seattle to El Paso and El Paso to Chicago, San Francisco and Honolulu. The equipment was all manufactured in Palo Alto.

3. The first three-stop amplifier, which was developed by Dr. Lee de Forest, C. V. Logwood and H. B. Van Etten, working under C. W. Elwell at Federal Telegraph.

The three-stop amplifier was the forerunner of talkies, public address, sound recording, broadcasting, television, radiotelephony, telegraphy and transmission of pictures by wire and radio.

4. Equipment that was used at the Panama Pacific Exposition to broadcast between San Jose and San Francisco, five years before commercial broadcasting really started in the East.

5. The all-wave Kennedy receiver, which was manufactured in Los Altos in 1922. It had 17 dials, and an amplifier, which could be bought separately, had several more dials.

6. The first loudspeakers developed by Peter Jenson and E. S. Pridham, who formed the Magnavox Company in San Francisco.

7. The first prototype of the two-way radio for aircraft, which was designed by Herbert Hoover, Jr., a radio engineer for Eastern Air Express, who studied under Prof. Frederick Terman at Stanford University.

8. The early products of Philip T. Farnsworth, who contributed a string of inventions in television, several of which are still embodied in almost all the televisions now in use. In 1928, Farnsworth showed the first all-electric television on a closed circuit.

9. The first glass working lathe, which was developed by Litton Engineering Laboratories and is now used by every vacuum tube company in the United States.

10. The Klystron, the first practical generator of microwave energy, which was developed by Russell and Sigurd Varian while working as research associates at Stanford University.

11. The resistance-tuned audio oscillator, which was produced in a garage by Bill Hewlett and Dave Packard, two Stanford University men who founded the Hewlett-Packard Company.

Ralph B. Austrian has been appointed West Coast Manager for Allen B. Du Mont Laboratories, Inc., and will make his office at Du Mont's west coast headquarters, 11845 Olympic Blvd., Los Angeles 64. Mr. Austrian, a Fellow of this Society, has also served as its Treasurer and Financial Vice-President and on its Engineering Committees. He has long been active in executive capacities in sales and administration in radio, motion-picture and television interests, having been associated with Radio Westinghouse Electric and Mfg. Co., Kolster Radio Div. of International Telephone and Telegraph Corp., Radio Corp. of America, the War Production Board, and RKO Television Corp.

Membership Certificates (Active and Associate members only). Attractive hand-engrossed certificates, suitable for framing for display in offices or homes, may be obtained by writing to Society headquarters, at 55 West 42d St., New York 36, Price: $2.50.

Papers Presented at the Chicago Convention April 18–22, 1955

Compared with the printed program received by those who attended the Convention, the following shows certain papers which were read by title only, and three papers which were not read are omitted.

Publication of Convention papers proceeds as promptly as possible. One of these appeared in the May *Journal* and several appeared in June. About three-fourths of these will be put into final, publishable form by the authors and most will be published by November. Some of those listed are demonstrations or only oral presentations for which no printed versions are to be expected.

MONDAY AFTERNOON—Sound

Some Practical Elements of 16mm Motion-Picture Sound Recording, ALLEN JACOBS, *The Calvin Company, Kansas City, Mo.*

Sound Effects Track Noise-Suppressor, J. F. BYRD, *Radio Corp. of America, Camden, N. J.*

Arricord 35, a New Double-System 35mm Recording Camera, ROBERT RICHTER, *Arnold & Richter Co., Munich*

Status of Magnetic Sound Standards—a Subcommittee Report, E. W. D'ARCY, *Ellis W. D'Arcy & Associates, Chicago*

MONDAY EVENING—Nontheatrical Motion Pictures Session

Film on Animation Techniques (a film demonstration), JOHN OXBERRY, *The Animation Equipment Corp., New Rochelle, N.Y.*

Two Animation Stands of New Design, E. H. BOWLDS, *E. H. Bowlds Engineering, Los Angeles*

Use of CinemaScope in 16mm Nontheatrical Films, JERRY FAIRBANKS, *Jerry Fairbanks Productions, Hollywood*

Some Basic Elements of 16mm Projector Design (read by title only), M. G. TOWNSLEY, *Bell & Howell Co., Chicago*

Arc Lamps for 16mm Projectors, ROBERT S. FREEMAN, *Strong Electric Corp., Toledo, Ohio*

Screens and Rooms (read by title only), GERHARD LESSMAN, *Bell & Howell Co., Chicago*

TUESDAY MORNING—Nontheatrical Motion Pictures

Film Cataloging at Moody Institute of Science, LEWIS H. HUMPHREY, *Moody Institute of Science, Los Angeles*

Multiple Camera Control, IRWIN A. MOON and F. ALTON EVEREST, *Moody Institute of Science, Los Angeles*

Selected Set Construction Techniques, HERBERT MEYER, *Motion Picture Research Council, Hollywood*

A New Color Meter for Tungsten and Daylight, ALLEN STIMSON, *General Electric Co., Lynn, Mass.*

16mm Away from Hollywood, RUDY SWANSON, *Rudy Swanson Productions, Appleton, Wis.*

TUESDAY AFTERNOON—Nontheatrical Motion Pictures

Analysis of Cost Characteristics of Business Motion Pictures, *John Flory, Eastman Kodak Co., Rochester, N.Y.*

A Survey of the Distribution of Nontheatrical Motion Pictures, HERBERT E. FARMER, *Dept. of Cinema, Univ. Southern California, Los Angeles*

Theory and Application of Pre-Production Testing for 16mm Nontheatrical Films, NICHOLAS ROSE, *Dept. of Cinema, Univ. Southern California, Los Angeles*

A Report from the Association of Cinema Laboratories, NEAL KEEHN, *The Calvin Company, Kansas City, Mo.*

A Film Age for Education, PHILIP A. JACOBSEN, *Motion Picture Unit, University of Washington, Seattle*

TUESDAY EVENING—Nontheatrical Motion Pictures

Filming an Educational Television Series, REID H. RAY, *Reid H. Ray Film Industries, St. Paul*

Infrared Motion-Picture Technique in Observing Audience Reactions, BERNARD R. KANTOR, *Dept. of Cinema, Univ. Southern California, Los Angeles*

How Walt Disney's Naturalist-Photographers Film Wildlife for the True-Life Adventures, ALFRED MILOTTE, *Walt Disney Productions, Burbank, Calif.*

Specialized Lighting and Set Techniques for a Nontheatrical Production, NICHOLAS WEBSTER (sponsored by) *Capital Film Laboratories, Washington, D.C.*

WEDNESDAY MORNING—Television

New 16mm Television Magnetic/Optical Sound Projector for the Limited Budget, JOHN S. POWERS and GEORGE F. KRTOUS, *Bell & Howell Co., Chicago*

Equipments for 16mm Magnetic Sound on Film Used in German TV Studios, KARL G. SCHWARZ, *Siemens & Halske, Karlsruhe*

16mm Magnetic Sound on TV News Film in Germany, ANN-RUTH MARTIN, *Suedwestfunk, Baden-Baden*

Experimental Considerations for 8mm Kinescope Recording, GEO. W. COLBURN, *Geo. W. Colburn Laboratory, Inc., Chicago*

Film Problems in Television News, SPENCER M. ALLEN, *WGN-TV, Chicago*

WEDNESDAY AFTERNOON—Television

Television Studio-Lighting—A Committee Report, H. M. GURIN, *Committee Chairman, National Broadcasting Co., New York*

Control of Light Intensity in Television Projectors, K. SADASHIGE and B. F. MELCHIONNI, *Radio Corp. of America, Camden, N.J.*

A 35mm Motion-Picture Projector for Color Television, W. F. FISHER and W. R. ISOM, *Radio Corp. of America, Camden, N.J.*

Chromacoder Colorcasting, PIERRE H. BOUCHERON, JR., *General Electric Co., Syracuse, N.Y.*

Experimental Equipment for Recording and Reproducing Color-Television Images on Black-and-White Film, WILLIAM L. HUGHES, *Engineering Experiment Station, Iowa State College, Ames, Iowa*

Integration of Color Television Equipment in a Television Station, PHILLIP B. LAESER, *WTMJ-TV, The Milwaukee Journal, Milwaukee*

Characteristics of the "Perfect" Lens and the "Perfect" Television System, OTTO SCHADE, *Tube Dept., Radio Corp. of America, Harrison, N.J.*

WEDNESDAY EVENING—Television

Color Television Vs. Color Motion Pictures, DONALD G. FINK, *Philco Corp., Philadelphia*

Development and Current Status of Television in Medical Education, RALPH P. CREER, *American Medical Assn., Chicago*

Low-Power Telecasting by the Armed Forces, LT-COL MEL WILLIAMSON and MAJ STANLEY E. RODBY, *Office of Armed Forces Information and Education, Washington*

Developments in Large-Screen Closed-Circuit Television, NATHAN L. HALPERN, *Theatre Network Television, Inc., New York*

THURSDAY MORNING—(Concurrent Session)

——————Symposium on Wide-Screen Photography

The Role of Resolving Power and Acutance in Photographic Definition, G. C. HIGGINS and R. N. WOLFE, *Eastman Kodak Co., Rochester, N.Y.*

The Effect on Definition of the Stage at Which Reduction Is Performed in Reduction-Printing Processes, G. C. HIGGINS, R. L. LAMBERTS and R. A. PURDY, *Eastman Kodak Co., Rochester, N.Y.*

Depth of Field and Perspective Considerations in Wide-Screen Cinematography, R. N. WOLFE and F. H. PERRIN, *Eastman Kodak Co., Rochester, N.Y.*

Improvements in CinemaScope, E. I. SPONABLE and H. E. BRAGG, *Twentieth Century-Fox Film Corp., New York*

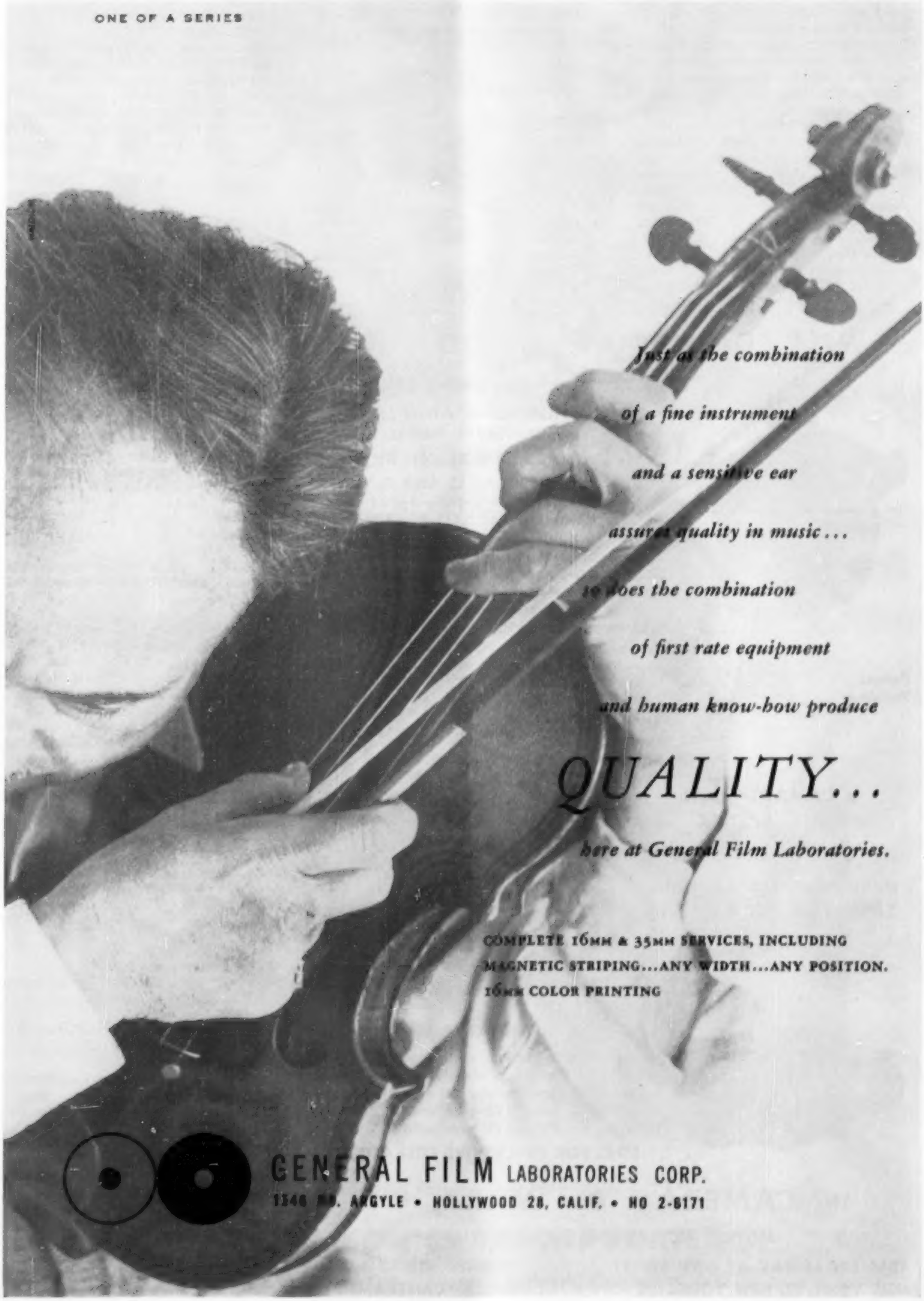
The VistaVision Process, LOREN L. RYDER, C. R. DAILY and JACK BISHOP, *Paramount Pictures Corp., Hollywood*

VistaVision Demonstration, C. R. DAILY, *Paramount Pictures Corp., Hollywood*

THURSDAY MORNING—(Concurrent Session)

——————High-Speed Photography

Color Schlieren for High-Speed Photog-



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raphy, GEORGE E. HAYS, *The Boeing Airplane Co., Seattle*

Controlled Tests to Evaluate the Accuracy of Accelerations Derived from the Analyses of High-Speed Camera Film Using a Bausch & Lomb Contour Measuring Projector, DERWYN SEVERY and PAUL BARBOUR, *Institute of Transportation and Traffic Engineering, Univ. California, Los Angeles*

Cameras and Lights for Underwater, HAROLD E. EDGERTON, *Massachusetts Inst. of Technology, Cambridge, Mass., and* LLOYD D. HOADLEY, *Woods Hole Oceanographic Inst., Woods Hole, Mass.*

Sensitometer With Electronic Flash Illumination, CHARLES W. WYCKOFF and HAROLD E. EDGERTON, *Edgerton, Germeshausen and Grier, Inc., Boston*

THURSDAY AFTERNOON—(Concurrent Session)

——————Laboratory Practices

Effect of Nitrogen Oxide Gases on Processed Acetate Film, J. F. CARROLL and J. M. CALHOUN, *Eastman Kodak Co., Rochester, N.Y.*

Recent Developments in Magnetic Striping by the Lamination Process, RICHARD F. DUBBE, *Minnesota Mining & Manufacturing Co., St. Paul, Minn.*

A Comparison of Soundtrack Processing Methods for Color Release Positive Film, JOHN L. FORREST, *Ansco, Binghamton, N.Y.*

A Multiple Magnetic Printing Equipment for CinemaScope, HANS-CHRISTOPH WOHLRAB, *Siemens & Halske A.G., Karlsruhe, West Germany*

Model "D" and "J" Printer Improvements, PAUL J. RICHARTZ and ARTHUR C. MUELLER, *Bell & Howell Co., Chicago*

THURSDAY AFTERNOON—(Concurrent Session)

——————High-Speed Photography

Time-Lapse Photography, JOHN NASH OTT, JR., *John Ott Pictures, Inc., Winnetka, Ill.*

Scientific Photography of Nuclear Explosions, LEWIS FUSSELL, JR., *Edgerton, Germeshausen and Grier, Inc., Boston*

A Rugged and Efficient High-Speed Photographic Illumination System, J. M. NOVAJOSKY, *Allison Div., General Motors Corp., Indianapolis*

Simultaneous High-Speed Framing and Streak Recording with a 16mm Fastax, GEORGE E. HAYS, *The Boeing Airplane Co., Seattle*

FRIDAY MORNING—Illumination, Studio and Process, Incandescent, General

Reliability Engineering, C. M. RYERSON, *Radio Corp. of America, Camden, N.J.*

Motion-Picture Studio Lighting and Process Photography—An SMPTE Committee Report, PETRO VLAHOS, *Motion Picture Research Council, Hollywood*

A Means and Method for Evaluating the Potential Efficiencies of Incandescent-Light Sources for Slide Projectors, J. A. VAN DEN BROEK, *Argus Cameras, Inc., Ann Arbor, Mich.*

Single-System Printing Device for Bell & Howell Model "J" Printer, ROBERT VANCE, *Byron, Inc., Washington, D.C.*

A System of High-Speed, High-Temperature Reversal Processing, LESTER E. BERND, *The Delaware Steeplechase & Race Assn., Wilmington, Del.*

FRIDAY AFTERNOON—Wide-Screen and Screen Brightness

Ambient Light from Motion-Picture Projectors, JOHN R. MILES, *John R. Miles Co., Skokie, Ill.*

An Aspheric Lens for Mirror-Type Motion-Picture Projection Systems, R. E. HARRINGTON, *National Carbon Co., Cleveland*

Evaluation and Reaction to New Processes of Motion-Picture Presentation, LUCIEN E. POPE, *Fox Midwest Amusement Corp., and* RICHARD H. OREAR, *Commonwealth Theatres, Inc., Kansas City, Mo.*

Preliminary Survey of Drive-in Theaters by the Screen Brightness Committee, FREDERICK J. KOLB, JR., *Eastman Kodak Co., Rochester, N.Y.*

current literature

The Editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic or microfilm copies of articles in magazines that are available may be obtained from The Library of Congress, Washington, D.C., or from the New York Public Library, New York, N.Y., at prevailing rates.

American Cinematographer vol. 36, Apr. 1955
An All-Film Television Station (p. 203) *G. Wentzel*
Shooting "Oklahoma!" in Todd-AO (p. 210) *H. A. Lightman*
Suiting the Lens to the Scene (p. 213) *C. Loring*
Experiments with the Camera (p. 214) *H. Benson*
Time Lapse Cinematography (p. 228) *Carroll Dunning*

vol. 36, May 1955
Filming Auto Race Thrills for "The Racers" (p. 272) *H. A. Lightman*
Cinematography in Parachute Research (p. 275)
Something New in Camera Cranes (p. 278) *G. Roe*
'Electronicam'—Du Mont's New Dual-Recording TV-Film Camera (p. 280)
20th-Fox Develops "Zoom" Spotlight (p. 306)

British Kinematography vol. 26, Apr. 1955
The Cinema Screen (p. 106) *R. Robertson*

vol. 26, No. 5, May 1955
The Impact of Television Films (p. 126) *H. Huth*
Lighting for Scientific Film Production (p. 134) *J. A. S. Turner*

Colour Processes in Industrial Film Production (p. 139) *D. Ward*

Electronics vol. 28, June 1955
Color-Video Envelope-Delay Measurement (p. 144) *R. C. Kennedy and H. French*

Film World vol. 11, June 1955
Multiple Camera System Combines Flexible Features of TV Systems (p. 294)

Ideal Kinema vol. 21, Apr. 7, 1955
Ingenious Camera Records Screen Brightness (p. 9)

Industrial Photography vol. 4, No. 3, May–June 1955
High Speed Schlieren (p. 24) *L. B. Walton*

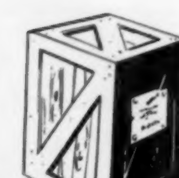
International Projectionist vol. 30, Apr. 1955
The Development of the Motion Picture Projector (p. 15) *T. Armat*
The Improved Strong '135' Projection Arclamp (p. 16) *A. J. Hatch*
Light Sources for Film Projection (p. 10) *R. A. Mitchell*
vol. 30, No. 5, May 1955
'Matching' Apertures and Lenses (p. 7) *R. A. Mitchell*
Video-Film Camera (p. 22) *A. Simon*

Kino-Technik vol. 9, Mar. 1955
Die Möglichkeiten der Fernseh-Grossprojektion in den Filmtheatern (p. 68) *Dr. Jensen*
Die Bedeutung des Films im britischen Fernsehen (p. 72)
Der heutige Entwicklungsstand des Farbfernsehens (p. 78) *W. Knobloch*
45 Jahre Fernbildübertragung mit Magnetbandtechnik (p. 81) *H. Atorf*
vol. 9, Apr. 1955
Der Schmalfilm als Wirtschaftsfaktor (p. 102) *H. H. Grassmann*
Getriebe als Bauelemente der Schmalfilmkamera (p. 112) *H. Weise*
Die Tonqualität beim 8-mm-Schmalfilm mit Magnetspur (p. 118) *Friedrich*
Umkehrfilme in der Praxis des Schmalfilm-Amateurs (p. 121)
Reflexions-Eigenschaften verschiedener Projektionswände (p. 124) *J. Saget*
Teleskopische Vorsatzoptik für die Schmalfilm-Kamera (p. 130) *H. Naumann*
vol. 9, May, 1955
Film-Synchronisation; ihre Technik und Gestaltung (p. 152)
Die Synchronisation von Stereo- und Breitbildfilmen (p. 154) *E. Leistner*
Tonbearbeitungsverfahren bei der Synchronisation (p. 162) *W. Grau*
Moderne Synchronisationsanlagen in Deutschland (p. 168)
75 Jahre Perutz—auch ein Gedenktag für den Film (p. 172)
Schmalfilm-Projektor "Leitz G 1" jetzt mit Magnetton (p. 174)

Motion Picture Herald (**Better Theatres Section**) vol. 199, May 1955
Combining System Elements for Best Picture Lighting (p. 21) *G. Gagliardi*
Horizontal Projection with Sound on the Picture Film (p. 25) *F. Hall*
vol. 199, June 11, 1955
Practical Considerations of Speed in Projection Optics (p. 22) *G. Gagliardi*
VistaVision at New York's Criterion with Horizontal Projection for a 45-Foot Picture (p. 28)

Power and Works Engineering vol. 49, Aug. 1954
Uses of Industrial Television (p. 267) *L. Walter*

Tele-Tech vol. 14, June 1955
"Electronicam" Unites TV and Film Operations (p. 95)

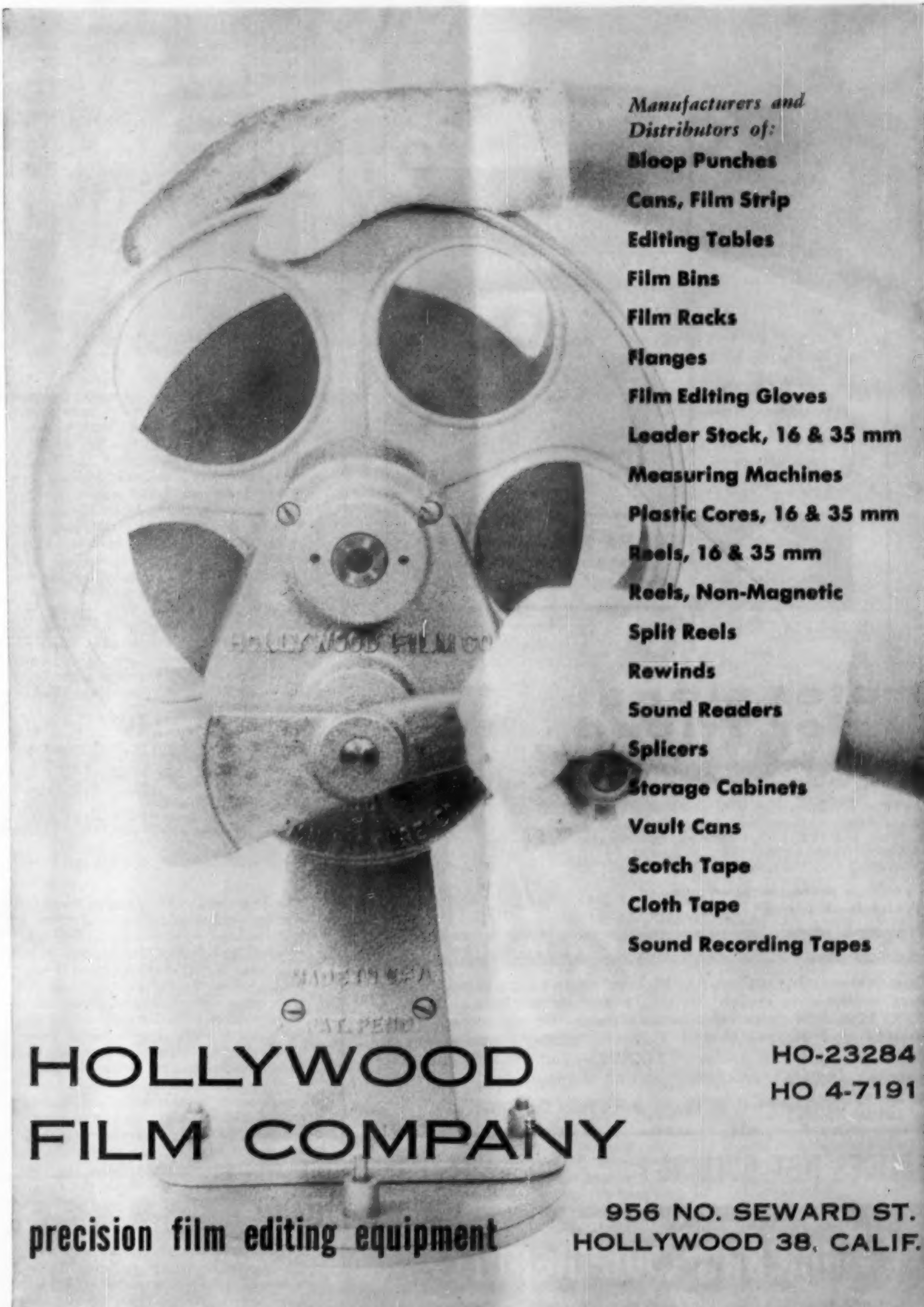


new products (and developments)

Further information about these items can be obtained direct from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of these items does not constitute endorsement of the products or services.

Kodak High Resolution Plates, used in the manufacture of optical instruments, are described in literature available from the Special Products Sales Div., Eastman Kodak Co., Rochester 4, N.Y. Of interest to reticle makers and precision instrument builders, these plates have a resolving power known to exceed 1,000 lines/mm (25,000 lines/in.) and have been recently further improved to guard against microscopic imperfections.

Peerless Reconditioning is an 8-page booklet describing phases of reconditioning such as cleaning, scratch removal, re-


Manufacturers and
Distributors of:
Bloop Punches
Cans, Film Strip
Editing Tables
Film Bins
Film Racks
Flanges
Film Editing Gloves
Leader Stock, 16 & 35 mm
Measuring Machines
Plastic Cores, 16 & 35 mm
Reels, 16 & 35 mm
Reels, Non-Magnetic
Split Reels
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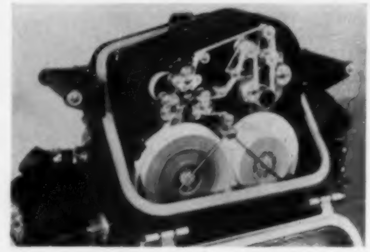
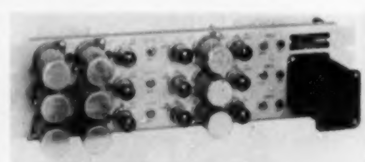
FILM COMPANY
HO-23284
HO 4-7191
precision film editing equipment
956 NO. SEWARD ST.
HOLLYWOOD 38, CALIF.

humidification, repairs, replacements, salvaging, the Peerless Treatment and Peer-Renu, issued by Peerless Film Processing Corp., 165 W. 46 St., New York 36. Much of this information has been published as an article, "Why Recondition Your Films?," in the June 1955 issue of *Audio-Visual Guide*.



The Arricord 35 is a newly designed "single-unit" double-system picture and sound recording camera recently introduced for the Munich firm of Arnold & Richter by Kling Photo Corp., 235 Fourth Ave., New York 3. It is described as a very compact new outfit which is a combination of the latest Arriflex 35, Model IIA camera, with a magnetic sound recording unit using 17½mm film, both housed in a single sound blimp with external controls. The Arricord 35 can be operated away from the usual studio facilities because of its 24-v battery power supply. Through-the-lens focusing and viewing permit camera operation by a single cameraman; duplicate controls are provided for an assistant. The Arricord 35, complete with three lenses, amplifiers, and batteries is priced at $9,000.



The Type 5437-A Distribution Amplifier is a three-strip amplifier designed for use as a pulse-distribution, video-distribution or sync-mixing amplifier. Its excellent phase and linearity characteristics make it ideal for color-system video distribution as well as for monochrome applications. As a video-distribution or pulse-distribution amplifier, this unit provides three separate inputs with bridging facilities, six outputs, and handles either positive or negative pulses with provisions for polarity reversals.

For use as a sync-mixing amplifier for mixing a video signal with sync to form a composite video signal, provisions are made for a video input jack with bridging facilities, a sync input jack, and one composite output jack. Since this unit is comprised of three separate amplifier strips, all three functions, pulse, video and sync mixing, may be performed simultaneously on the same unit with no crosstalk. Additional information, including Bulletin TR-825, is available from Allen B. Du Mont Laboratories, Inc., 1500 Main Ave., Clifton, N.J.

employment service

These notices are published for the service of the membership and the field. They are inserted three months, at no charge to the member. The Society's address cannot be used for replies.

Positions Wanted

Theater Engineering Manager. Seeking position with large theater circuit or equipment manufacturer. Can assume all responsibility involved in planning, procurement, installation and service of sound and projection equipment; also stage, seating, air conditioning and heating, construction, maintenance entire physical theater and real estate properties. Sales and export experience in High Fidelity. B.S. in E.E. Member SMPTE and licensed professional engineer State of N.J. Over 20 yr experience. C. J. Bachman, 111 Halsted St., E. Orange, N.J.

TV/Motion-Picture Coordination. Registered professional consulting engineer with unique combination experience in TV/film and live production, broad administrative and demonstrated technical ability, can bring technical knowledge and production experience to bear on commercial film production and do shirt-sleeve work. Experience includes executive TV work in major agency, writing and producing commercials, and national networks. Author of 3 books and scores of articles; TV consultant to universities; also professor teaching *all* phases TV and TV films; able to get along with people; well-known in industry, speaker, active in industry committees, NTSC, Senior Member IRE, SMPTE. Age 39. Write: c/o Hewitt, 4515 Saul Rd., Kensington, Md.

16mm Cameraman. 15 yr experience; age 41. Last 7 yr as head cinematographer in medical college shooting color exclusively; editing and some animation, also all-round still and lab work, black-and-white and color. Seeking permanent position; complete résumé from: Robert A. Leonard, 2100 10th Ave. South, Birmingham 5, Ala.

Television Floor Manager. Young married man desires TV floor position with aggressive station. Recently completed film seminar at New School (New York). Show business background; acting, directing. Will locate anywhere. Write: Joseph R. Masefield, 15 Berkeley Place, Brooklyn 17, N.Y.

Positions Available

Audio Laboratory Engineering Assistant. Will set up, operate and maintain audio equipment in Audio Division of major consumer testing organization; will construct auxiliary equipment as required; will assist division head and others in testing audio equipment sold to public. Required—degree in electrical engineering or equivalent experience; also 3–4 yr experience in audio equipment operation and maintenance; some familiarity with theory and mathematics of audio electronics and acoustics. Salary $100 up depending on individual. Send résumé to Personnel Director, Consumer Reports, 17 Union Sq. West, New York 3.

Partnership available to experienced motion-picture technician in small film concern. Desire and ability to be "own boss" imperative. Requisites: Recording, editing, camera, special effects, animation skills—initiative, drive, intelligence, flexibility and inventiveness. Sales ability and administrative aptitude essential. Resume in letter form stating pertinent facts and full expression of personal and vocational objectives will be accorded strict confidence. Graphic Films, 104 West 43 St., New York 36.

B.S. or M.S. Physicist or Electrical Engineer with experience in photographic or magnetic sound recording. Will serve under Process Supervisor to investigate problems of photographic sound quality. Knowledge of film printing and processing equipment, recording methods, and film sensitometry desirable. Salary open. Send brief résumé incl. approx. salary requirements to E. E. Griffith, Technicolor Motion Picture Corp., 6311 Romaine St., Hollywood 38, Calif.

Film Inspectors: Permanent or summer positions open. Telephone or write — Mr. Kern Moyse or Miss Annabel Compton, Peerless Film Processing Corp., 165 W. 46 St., New York 36.

Require experienced 16mm motion picture laboratory technician for position as lab supervisor for growing motion-picture laboratory. Must be thoroughly experienced in control and processing color and B&W motion-picture films. Salary and percentage to man who can qualify. Send résumé and references to Western Cine Service, Inc., 114 E 8th Ave. Denver 3, Colo.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***Reg. U.S. Patent Office**

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News Columns

Advertisers

Meeting Calendar

National Audio-Visual Association, Convention and Trade Show, July 22–27, Hotel Sherman, Chicago

Biological Photographic Association, Annual Meeting, Aug. 30–Sept. 2, Wisconsin Hotel, Milwaukee.

American Chemical Society, National Meeting, Sept. 11–16, Minneapolis, Minn.

Illuminating Engineering Society, National Technical Conference, Sept. 12–16, Hotel Statler, Cleveland, Ohio

Instrument Society of America, Sept. 12–16, Shrine Exposition Hall and Auditorium, Los Angeles.

National Electronics Conference, Oct. 3–5, Hotel Sherman, Chicago.

78th Semiannual Convention of the SMPTE, Oct. 3–7, Lake Placid Club, Essex County, N.Y.

American Institute of Electrical Engineers, Fall General Meeting, Oct. 3–7, Morrison Hotel, Chicago.

Photographic Society of America, Oct. 5–8, Sheraton-Plaza Hotel, Boston, Mass.

Optical Society of America, Oct. 6–8, Hotel Wm. Penn, Pittsburgh, Pa.

Audio Engineering Society, Oct. 12–16, Hotel New Yorker, New York.

American Standards Association, 37th Annual Meeting and Sixth Annual Conference on Standards, Oct. 24–26, Washington, D. C.

American Rocket Society, Nov. 13–18, Chicago.

American Society of Mechanical Engineers, National Meeting, Nov. 13–18, Hotels Congress, Hilton and Blackstone, Chicago.

American Institute of Chemical Engineers, Nov. 27–30, Hotel Statler, Detroit.

Acoustical Society of America, Dec. 15–17, Brown U., Providence, R. I.

Optical Society of America, Apr. 5–7, 1956, Bellevue-Stratford, Philadelphia, Pa.

79th Semiannual Convention of the SMPTE, Apr. 29–May 4, 1956, Hotel Statler, New York.

80th Semiannual Convention of the SMPTE, Oct. 7–12, 1956, Ambassador Hotel, Los Angeles.

Optical Society of America, Oct. 18–20, 1956, Lake Placid Club, Essex Co., N.Y.

Optical Society of America, Mar. 7–9, 1957, Hotel Statler, New York.

81st Semiannual Convention of the SMPTE, Apr. 28–May 3, 1957, Shoreham Hotel, Washington, D.C.

82d Semiannual Convention of the SMPTE, Oct. 6–11, 1957, Hotel Statler, New York.

83d Semiannual Convention of the SMPTE, April 20–26, 1958, Ambassador Hotel, Los Angeles.

84th Semiannual Convention of the SMPTE, Oct. 1958, The Drake, Chicago.

85th Semiannual Convention of the SMPTE, May 3–8, 1959, Fontainebleau, Miami Beach, Fla.

SMPTE Officers and Committees: The rosters of the Officers of the Society, its Sections, Subsections and Chapters, and of the Committee Chairmen and Members were published in the April Journal.

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